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GEOLOGY AND MINERAL RESOURCES OF THE SABULA AND PENFIELD QUADRANGLES, CLEARFIELD, ELK, AND JEFFERSON COUNTIES, PENNSYLVANIA

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COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
BUREAU OF
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

Atlas 74ab

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by Thomas M. Berg and Albert D. Glover
Pennsylvania Geological Survey

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CONTENTS

Page

Preface iii
Abstract 1
Introduction 2
  Scope of the report 2
  Location 2
  Physiography 3
  Field work and methods of investigation 4
  Acknowledgements 5
Previous work 6
Stratigraphy 7
  Subsurface stratigraphy 7
    Introduction 7
    Upper Silurian strata 7
      Salina Group 7
      Bass Islands Group 8
    Lower Devonian strata 8
      Helderberg Formation 8
      Oriskany Group 8
      Onondaga Formation 9
    Middle Devonian strata 9
      Tioga "bentonite" 9
      Hamilton Group 9
      Tully Formation 9
    Upper Devonian strata 10
      Nomenclatural considerations 10
      Genetic considerations 10
      Lithologic characteristics and thickness 11
    Nature of Devonian-Mississippian stratigraphic boundary 11
    Mississippian strata 12
  Surface stratigraphy 13
    Mississippian strata 13
      Pocono Formation 13
    Mississippian-Pennsylvanian unconformity 16
    Pennsylvanian strata 18
      Sabula drill hole 18
      Pennsylvanian stratigraphic terminology 19
      Pottsville Group 19
        General 19
        Elliott Park Formation 19
        Curwensville Formation 20
        Pottsville Group undivided 22

Page
Allegheny Group 26
General 26
Clearfield Creek Formation 27
Millstone Run Formation 29
Mineral Springs Formation 32
Laurel Run Formation 33
Glen Richey Formation 34
Conemaugh Group 36
Quaternary alluvium 38
Geologic history 38
General 38
Cambrian, Ordovician, and Silurian Periods 39
Devonian Period 40
Mississippian Period 41
Pennsylvanian Period 42
Post-Pennsylvanian time 45
Quaternary Period 45
Structural geology 45
Introduction 45
Structural datum planes 46
Folds 47
Faults 47
Joints 49
Mineral resources 51
Coal 51
General 51
Chemical and physical characteristics 51
Coal reserves 61
Clay and clay shale 64
Limestone 69
Construction materials 72
Crushed sandstone 72
Siltstone and silt shale 73
Sand and gravel 74
Natural gas 76
General 76
Factors controlling gas accumulation 77
Producing horizons 77
Onondaga-Ridgeley ("Oriskany") interval (deep well production) 77
Upper Devonian sands (shallow well production) 87

Page
Water 87
Surface water 87
Ground water 88
Engineering geology 90
References 91
Glossary 93
Appendix 1. Log of Brockway water well cuttings . . . . . . *microfiche*, p. A1
Appendix 2. Measured sections and descriptions of the Pocono Formation . . . . *microfiche*, p. A4
Appendix 3. Detailed description of the Sabula drill hole core . . . . *microfiche*, p. A10
Appendix 4. Detailed description of the Pennsylvania Railroad drill hole core . . . . *microfiche*, p. A38
Appendix 5. Measured sections of the Allegheny Group . . *microfiche*, p. A43
Appendix 6. Measured sections of the Conemaugh Group . *microfiche*, p. A60
Appendix 7. Measured sections of clays, clay shales, and limestones . . . . *microfiche*, p. A70
Appendix 8. Firing tests and physical data on clays and clay shales . . . . p. A73 (follows p. 98 in text)

ILLUSTRATIONS

FIGURES

Figure 1. Map showing physiographic provinces of Pennsylvania and location of the report area 3
2. Map and profile showing lower Pocono exposures on the southeastern flank of Boone Mountain along Wilson Run . . 15
3. Photograph showing crossbedding in Upper Connoquenessing Sandstone exposed on eastern shore of Parker Dam Lake 20
4. Photomicrograph of Homewood Sandstone from Panther Rocks area 21
5. Photomicrograph of Pottsville subphyllarenite from Sabula drill hole 23
6. Photograph showing plant impression in Pottsville sandstone from Boone Mountain 24
7. Photograph showing quartz-pebble conglomerate in Pottsville Group on Boone Mountain 25
8. Photograph showing massive Pottsville sandstone above Pete Buck Hollow 25

Page
Figure 9. Photograph showing massive Pottsville conglomerate 26
10. Photomicrograph of metamorphic quartzite pebble from the basal Pottsville conglomerate on Boone Mountain 27
11. Photomicrograph of strongly deformed, recrystallized metamorphic quartzite pebble from the basal Pottsville conglomerate on Boone Mountain 28
12. Photograph showing exposure of the Millstone Run Formation in an abandoned strip mine 30
13. Photograph showing asymmetrical ripple marks in the Millstone Run Formation 30
14. Photograph showing Millstone Run Formation near Middle Branch of Wilson Run 31
15. Photograph showing Millstone Run Formation at the Horning Run heading of the Lady Jane mine 32
16. Map showing subsurface structural geology, based on the "Oriskany" (Ridgeley) Sandstone, and limits of gas fields and pools 48
17. Rose diagram showing joint bearings in the Sabula and Penfield quadrangles 50
18. Photomicrograph of Vanport Limestone from 510.5 feet in the Sabula drill hole 69
19. Photomicrograph of Vanport Limestone from 511.2 feet in the Sabula drill hole 70
20. Photomicrograph of Johnstown Limestone from the Sabula drill hole 71
21. Photograph showing sand and gravel pit (upper level) in Quaternary alluvium along Little Toby Creek 74
22. Histograms showing sediment size distribution in Quaternary alluvium along Little Toby Creek 75
23. Photograph showing alluvium in upper level of sand and gravel pit along Little Toby Creek 76

PLATES

(in envelope)

Plate 1. Geologic map of the Sabula and Penfield quadrangles, Clearfield, Elk, and Jefferson Counties, Pennsylvania.
2. Sections from gas well records showing Upper Devonian, Mississippian, and Pennsylvanian strata across the Mountain Run fault and Boone Mountain anticline.

Plate 3. Sections from gas well records showing Upper Devonian, Mississippian, and Pennsylvanian strata.
4. Sections from gas well records showing Upper Devonian, Mississippian, and basal Pennsylvanian strata.
5. Long drill holes and measured sections showing Pennsylvanian strata.
6. Millstone Run Formation stratigraphic sections.
7. Lower Kittanning no. 3 coal reserves and measured sections.
8. Additional coals and mined-out areas.
9. Location of measured clay and clay shale sections.
10. Foundation and excavation conditions and major watersheds.

TABLES

Page
Table 1. Analyses of coal samples from the Sabula and Penfield quadrangles 52
2. Published analyses of coal as shipped or delivered from the Sabula and Penfield quadrangles 58
3. Published analyses of mine samples of coal from the Sabula and Penfield quadrangles 60
4. Lower Kittanning coal reserves in the Sabula and Penfield quadrangles 62
5. Thickness and stratigraphic position of clays, clay shales, and limestones in the Sabula and Penfield quadrangles 64
6. Deep natural gas wells in the Sabula and Penfield quadrangles 78
7. Shallow natural gas wells in the Sabula and Penfield quadrangles 85
8. Chemical analyses, in parts per million, of streams in the West Branch Susquehanna River basin near Clearfield, Pennsylvania 89

GEOLOGY AND MINERAL RESOURCES OF THE SABULA AND PENFIELD QUADRANGLES, CLEARFIELD, ELK, AND JEFFERSON COUNTIES, PENNSYLVANIA

by

Thomas M. Berg and Albert D. Glover

ABSTRACT

The Sabula and Penfield 7½-minute quadrangles are located in west-central Pennsylvania within the Appalachian Plateaus physiographic province. The topography of this area reflects broadly folded sedimentary rocks having varying resistance to erosion.

Extensive subsurface exploration and production of natural gas have provided stratigraphic information through the Devonian Helderberg Formation and into the upper 230 feet of the Silurian Salina Group. Bedrock exposures at the surface include most of the Mississippian Pocono Formation, and the Pennsylvanian Pottsville, Allegheny, and Conemaugh Groups. The interpretation of a regional unconformity between Mississippian and Pennsylvanian strata is based on an apparent erosional loss of Mississippian units and nondeposition of lower Pottsville units. Stratigraphic subdivision of the Pennsylvanian rocks is based on key beds (coal seams) rather than on lithologic homogeneity.

The lowermost bedrock units that are mapped at the surface in this area include sandstones, siltstones, and some shales of the Pocono Formation. These are overlain by Pennsylvanian formations comprising thin, cyclic sequences of shale, sandstone, siltstone, clay, coal, and sporadic freshwater limestone.

Structurally, the Sabula-Penfield area is traversed by the Punxsutawney-Caledonia syncline which trends northeast-southwest. The northwestern limb of the Chestnut Ridge anticline flanks the syncline on the southeast, and the Boone Mountain anticline flanks the syncline on the northwest. A major fault, the Mountain Run fault, has been located along the southeastern flank of Boone Mountain. Vertical displacement along this fault measures approximately 400 feet.

Coal is one of the principal mineral resources in the report area, although available information suggests that most of the major seams except the Lower Kittanning are too thin to be minable at present. Total reserves of the Lower Kittanning no. 3 coal over 28 inches thick are 150 million short tons. Natural gas is another im-

portant mineral resource; some production from both deep and shallow horizons is still in progress. A formerly producing shallow pool at Boone Mountain is now depleted and is currently being used for subsurface gas storage. Other potentially valuable resources in the area include clay, shale, sandstone, sand and gravel, and ground water.

The rocks in this report area are also classified and mapped according to their engineering characteristics and potential utility as construction materials.

INTRODUCTION

SCOPE OF THE REPORT

This report is part of a continuing series of detailed geological reports published by the Pennsylvania Geological Survey. The report covers the northern half of the Penfield 15-minute quadrangle and is published on the Sabula and Penfield 7½-minute topographic base maps. The area covered is approximately 112 square miles.

Recent mapping at the same scale (1:24,000) has been completed to the south, in the southern Penfield area (Edmunds and Berg, 1971), and to the southeast in the southern Clearfield (Glover, 1970), northern Houtzdale (Edmunds, 1968), and Philipsburg (Glass, 1972) areas. Work is presently being done in the southern Houtzdale (Glass and others, in press) and DuBois (Glover and Bragonier, in prep.) areas. This report will therefore provide a continuity of stratigraphic information for the region and will aid in regional stratigraphic interpretations.

The mineral resources section of the report covers the nature and occurrence of the major mineral resources present, and includes estimates of the remaining reserves of the Lower Kittanning coal.

The report is written for both professional and lay readers. Accordingly, an effort has been made to keep the language as simple as possible without sacrificing accuracy. Of necessity, technical geologic terms have occasionally been used, and these are defined in a glossary at the end of the report.

Thomas M. Berg compiled the geologic map of the Sabula quadrangle, and Albert D. Glover compiled the geologic map of the Penfield quadrangle. The written report has been a joint effort by both authors.

LOCATION

The Penfield and Sabula quadrangles lie between 41°07′30″ and 41°15′00″ north latitude, and between 78°30′00″ and 78°45′00″ west longitude. The area includes a portion of the City of DuBois; parts of Huston, Sandy, Pine, and Union Townships in Clearfield County; part of Snyder Township in Jefferson County; and parts of Horton, Fox, and Jay Townships in Elk County.

The data points shown on Plate 1 are located in the following manner. Each 15-minute quadrangle in Pennsylvania is divided into thirty-six 2½-minute blocks. Vertical columns of blocks are identified by capital letters—A, B, C, D, E, and F—at the top of the map. Horizontal rows of blocks are identified by lower case letters—a, b, c, d, e, and f—along the side of the map. From this system, for example, the northwesternmost 2½-minute block in the mapped area is designated Aa; the block just to the south is Ab, and the block immediately east is Ba. The data points in each block are numbered consecutively and roughly southwardly, as Aa1, Aa2, etc.

PHYSIOGRAPHY

The Sabula-Penfield area lies within the Appalachian Plateaus province, which includes most of western Pennsylvania (see Figure 1). This region is characterized by broad, open folds having gently dipping flanks. The Plateau is underlain by sedimentary rocks, which in this area measure approximately 16,000 feet in thickness (Am. Assoc. Petroleum Geol-

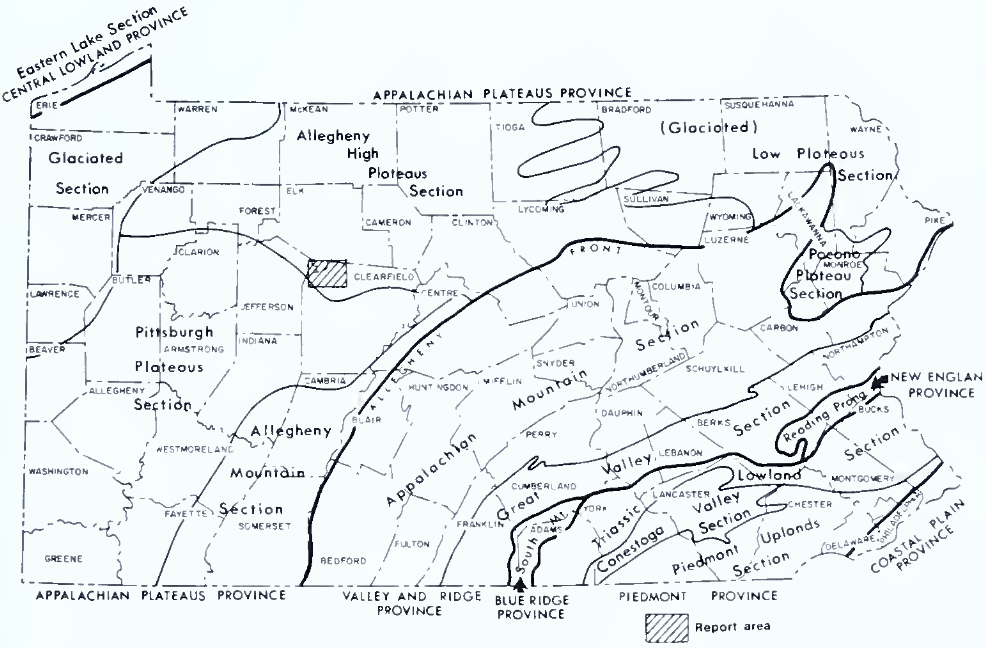

Figure 1. Physiographic provinces of Pennsylvania and location of the report area.

ogists Basement Rock Project Committee, 1967). A more complete discussion of the physiography and geologic history of the Appalachian Plateau may be found in Ashley (1933) and Fenneman (1938).

More specifically, this report area may be described as a region of highly dissected, rolling, relatively flat topped uplands. Most of the major streams are floored with alluvium. The majority of the small streams have broad V-shaped valleys, whereas the principal streams have rather wide cross-valley profiles and flat-bottomed floodplains.

In general, Allegheny and Conemaugh rocks include more shale than Pottsville and Pocono rocks. For this reason, the areas underlain by the Allegheny and Conemaugh Groups are less resistant to erosion and are more highly dissected by streams. The local relief varies from 100 to 400 feet in the Penfield and Sabula quadrangles.

Maximum altitudes in the area are found on Boone Mountain anticline, and the lowest altitudes along the axis of the Punxsutawney-Caledonia syncline. The highest point is located at the Lookout Tower on Boone Mountain, which has an altitude of 2369 feet. The lowest point is found in the northeast where Bennett Branch of Sinnemahoning Creek leaves the report area at an altitude of 1180 feet. The total relief of about 1200 feet reflects the exposures of the more resistant Pottsville and Pocono sandstones on the anticline and the presence of the less resistant Allegheny and Conemaugh rocks in the syncline.

The drainage of the Sabula-Penfield area consists of six watersheds (Plate 10). Sandy Lick Creek and Little Toby Creek flow westward to the Ohio River and the Gulf of Mexico. The remaining streams are all tributaries of the Susquehanna River which drains into the Atlantic.

Anderson Creek is one of the principal streams feeding the DuBois reservoir, which is located a short distance to the south of this report area. Much of the water supply for the Borough of Brockway is derived from Little Toby Creek and its tributaries. Parker Dam State Park is located in the Laurel Run watershed.

FIELD WORK AND METHODS OF INVESTIGATION

Field work in the Penfield and Sabula quadrangles was completed during portions of the field seasons from 1966 through 1970. Mapping was done on U. S. Geological Survey 7½-minute topographic base maps. Aerial photographs were used for precise field locations of all outcrop data. The locations of these data points were then transferred to the topographic maps.

All coal strip mines in the area were visited. Wherever possible, a measured section of the coal and overlying strata was made using a hand level and ruler. Other stratigraphic information was obtained from road and railroad cuts, from available drill records, and from studies of drill core from the area. Paleontological collections (both plant and invertebrate) were made during the course of field work.

Detailed stratigraphic correlations were made prior to final compilation of the geologic map. Considerable aerial photographic interpretation was done where little outcrop data were available, especially in the southeastern portion of the map area.

Faulting and unusual amplitude of folding required detailed study of the subsurface in the Boone Mountain area.

As part of the project, a 716-foot core drill hole was completed in the summer of 1969 in the northeastern part of the Sabula quadrangle, thus augmenting the stratigraphic information in the area.

ACKNOWLEDGEMENTS

We wish to extend special thanks to Mr. William E. Edmunds of the Pennsylvania Survey for our many helpful discussions and for his suggestions concerning various problems encountered during the course of study. We are grateful also for the assistance of Mr. William S. Lytle and the late Mr. Walter R. Wagner of the Survey's Oil and Gas Division in providing subsurface records. Thanks are also due Dr. Charles Helfrich, Mr. Thomas Swinehart and Mr. Stephen Potts for their assistance in completing the field work for this report.

We appreciate the information and records given us by Mr. John E. DuBois, Jr., Mr. A. J. Palumbo (New Shawmut Mining Company), Mr. Donald J. White (P. and N. Coal Company, Inc.), Mr. Paul Heinman (Lady Jane Collieries, Inc.), Mr. Irvan Stoker (Glen Irvan Corporation), and Mr. Ronald Landon (Moody Associates, Inc.). Mr. John Hess, Registered Engineer in Clearfield, the late Mr. Gerald Madison (former Yost Associates, Inc. in DuBois), and Mr. Walter Zimmerman, Registered Engineer in Punxsutawney, also provided much useful information. Mr. Wayne Leeper of United Natural Gas Company provided drilling records from the Boone Mountain shallow gas field. We acknowledge Mr. John Lambert, of the Pennsylvania Department of Transportation office in Clearfield, for providing soil survey reports. Information concerning drilling of a municipal water well in the Whetstone Branch area provided by Mr. William Kephart of Brockway Glass Company is appreciated.

Professor James D. Grierson of the State University of New York at Binghamton identified the Mississippian plants found in the Pa. Route 153 highway cuts on Boone Mountain, and his cooperation is gratefully acknowledged. Our discussions with Dr. Grierson concerning Mississip-

pian stratigraphy and paleobotanical aspects of the Pocono Formation were quite helpful.

Mr. Glascow Rector of Geological Sample Log Company kindly gave permission to publish information derived from several lithologic logs of deep gas well cuttings.

Finally, we thank all property owners and coal companies for their courtesy and cooperation in providing access to the area.

PREVIOUS WORK

Henry D. Rogers, State Geologist of the First Pennsylvania Geological Survey, made what was probably the first geological reconnaissance of the report area in 1838. As reported in Lesley (1876, p. 69-70), "Mr. Rogers spent all the time he could spare for personal field work in the northern counties, and as far south as Clearfield and Centre Counties; a country at that time an almost unbroken wilderness, roamed over by the elk and the panther. His object was to organize for the ensuing year a camp survey of this sixth district." (The sixth district encompassed those counties in north-central Pennsylvania which were north of the Allegheny Mountains, including the northern two thirds of Clearfield and Jefferson Counties.)

The first geological exploration was undertaken in 1840 by James T. Hodge, Townsend Ward, and for part of the field season by Peter Lesley, Jr., of the First Pennsylvania Geological Survey. These men, along with a party of assistants and miners, attempted to expose, by digging, the outcrops of all coal seams, limestone beds, iron ore beds, and any other mineral resources they might find. As reported in the Fifth Annual Report of the First Pennsylvania Survey (Rogers, 1841, p. 10-11), the area of this exploration covered portions of the Sabula-Penfield area, including Bennett Branch of Sinnemahoning Creek, where several coal seams and iron ore beds were discovered. Mr. Lesley and one companion also made a topographical and geological reconnaissance in 1841 in this general area, including the Little Toby Creek basin.

Apparently no other field work was done in the area of this report until 1874, when Franklin Platt of the Second Pennsylvania Geological Survey, with one, and later three assistants, mapped the coal fields of Clearfield and Jefferson Counties (Platt, 1875). This report was revised by H. M. Chance (1884), mainly because of errors in correlating the Homewood and Mahoning Sandstones and in locating the anticlinal axes. The geology of Elk County was completed by C. A. Ashburner and A. W. Sheafer during the field seasons of 1876 through 1879 (Ashburner and Sheafer, 1885).

Since that time, the geologic investigations undertaken in the area of this report have been of an economic nature involving limestone, shales and clays, gas, and ground water. Most of these are included in the references to this report. Two such reports bear mentioning. Mineral Resource Report 6, *Bituminous Coal Fields of Pennsylvania,* was published by the Fourth Pennsylvania Geological Survey (Ashley, 1928; Sisler, 1926; Reese and Sisler, 1928; U. S. Bureau of Mines, 1928). Part II of this bulletin (Sisler, 1926) discusses the stratigraphy, structure, and distribution of the various coal beds by county, including Clearfield, Elk, and Jefferson Counties. Mineral Resource Report 45 (Lytle and others, 1961), *A Summary of Oil and Gas Developments in Pennsylvania, 1955 to 1959,* contains a structural map by Addison S. Cate based on extensive deep gas well drilling that includes the Sabula-Penfield area.

No detailed geologic mapping has been done in the Sabula or Penfield quadrangles since the Second Pennsylvania Geological Survey studies cited above.

STRATIGRAPHY

SUBSURFACE STRATIGRAPHY

Introduction

Extensive drilling for natural gas in the Sabula and Penfield quadrangles has provided stratigraphic information down to the top of the Helderberg Group (Lower Devonian). One well (Logan L. Bond no. 1), at location Ca5 on top of Boone Mountain, penetrated 230 feet of Silurian strata below the Helderberg. More than 150 deep gas wells have penetrated the Lower Devonian "Oriskany" (Ridgeley) Sandstone; more than 25 shallow gas wells have penetrated producing gas sands of the Upper Devonian strata. However, a detailed subsurface study is beyond the scope of this report.

Upper Silurian Strata

Salina Group

In the Logan L. Bond no. 1 deep well at Ca5, the uppermost 130 feet of the Salina Group was encountered before drilling was completed. The total Salina Group is interpreted to be between 1200 and 1300 feet thick in the vicinity of this report area (Fergusson and Prather, 1968, p. 32). The upper portion of the group in this well is a very light gray to light-brownish-gray, dense, calcareous, argillaceous dolomite. It is occasionally silty and anhydritic; there are some pyritic traces in the upper 40 feet.

The presence of anhydrite increases downward and good stringers of anhydrite appear. The upper boundary of the group is based on the presence of anhydrite and is apparently gradational with the overlying Bass Islands Group.

Bass Islands Group

The Bass Islands (Keyser) Group overlies the Salina and is 100 feet thick in the Logan Bond well. Rocks in this group consist of slightly silty, calcareous dolomites and dolomitic limestones. The lower two thirds of the Bass Islands is light- to dark-brownish-gray, slightly argillaceous and silty, calcareous dolomite. The upper third is light- to dark-brownish-gray and grayish-brown, slightly argillaceous and pyritic, dolomitic limestone. The upper boundary of the Bass Islands is arbitrarily based on the uppermost occurrence of dolomite or dolomitic limestone.

Lower Devonian Strata

Helderberg Formation

The upper several feet of the Helderberg Formation has been penetrated in many of the deep gas wells along the northwestern flank of the Punxsutawney-Caledonia syncline. Jones and Cate (1957) indicate that the Helderberg is between 100 and 150 feet thick in the Sabula-Penfield area; however, in well Ca5, the Helderberg was only 65 feet thick.

The Helderberg is normally an impure, gray, cherty limestone. In well Ca5, it is dense, medium-dark-gray, argillaceous limestone, grading to very fine grained sandstone with some chert stringers in the upper part. It should be noted that the "Helderberg" of subsurface terminology in this part of Pennsylvania may, in fact, be partly equivalent to the Shriver Chert of the overlying Oriskany Group. There is often difficulty in differentiating Helderberg and Shriver sediments (Jones and Cate, 1957, p. 2), so the presence of Shriver should not be completely discounted.

Oriskany Group

The Oriskany Group overlies the Helderberg Formation and includes the Ridgeley Sandstone above, and Shriver Chert below. As noted, the Shriver, if present, may have been included in the Helderberg Formation. The Ridgeley Sandstone is referred to as "Oriskany" Sandstone in subsurface usage of western Pennsylvania. This is the gas-producing unit that has been of such great economic importance in this area. In the deep well at Ac7, the Ridgeley is a medium-gray, fine- to medium-grained (occasionally coarse grained), friable, quartzose sandstone. The grains are subrounded and show fair sorting. There is some trace of secondary recrystallization. In this report area, the sandstone varies from about 5 to 30 feet thick and theoretically thins to zero in a northwestern direction towards the "no sand" area of Jones and Cate (1957) and Cate (1962).

Onondaga Formation

The Onondaga Formation immediately overlies the Ridgeley Sandstone. Varying from less than 50 feet to almost 100 feet thick, the Onondaga consists of a lower chert and a thinner overlying limestone. In the deep well at Ca5, the upper 26 feet is limestone with some shale interbeds; the lower 73 feet is chert with some siltstone stringers. The limestone is dark gray and yellowish gray to medium dark brownish gray. It is micritic, argillaceous, pyritic, and fossiliferous (crinoids, ostracodes), with occasional streaks of black shale and siltstone. The chert is mottled medium gray and dark gray to black; well cuttings are translucent and silty. Some interbeds of brownish-gray dolomite were encountered in the Onondaga in the deep well at Fa22, but this "Onondaga" is at an abnormal depth and may be miscorrelated with older units.

Middle Devonian Strata

Tioga "Bentonite"

The boundary between the Onondaga Formation and the overlying Hamilton Group is often marked by the Tioga "bentonite." Where no bentonite is observed in well cuttings, its horizon is frequently observed in geophysical logs as a highly radioactive shale. Although often referred to as a metabentonite, the Tioga in the deep well at Ea15 is dusky-brown, micaceous, soft bentonitic clay with disseminated pyrite. It is apparently not more than a few feet thick.

Hamilton Group

The Hamilton Group is about 500 feet thick (plus or minus 50 feet), thinning generally from east to west across the report area (Jones and Cate, 1957). It is a fairly homogeneous sequence of black and brownish-black to medium-gray, calcareous, pyritic, hackly, brittle shales. The contact with the overlying Tully limestone is gradational in some wells.

Tully Formation

The Tully Formation thins from about 150 feet to about 50 feet thick in a north-northwest direction across the Sabula-Penfield area (Jones and Cate, 1957). The Tully consists of dark-gray, hard, argillaceous, slightly pyritic, micritic limestone having occasional beds of brownish-black, calcareous shale. The upper contact of the Tully limestone with the overlying Upper Devonian sediments is fairly sharp.

Upper Devonian Strata

Nomenclatural Considerations

The Upper Devonian section represents infilling of the Appalachian geosyncline with coarser terrigenous detrital sediments. In this part of Pennsylvania, two sets of stratigraphic names have been applied simultaneously to this sequence by geologists familiar with surface exposures to the east and northeast on the one hand and by geologists working on the subsurface of western Pennsylvania on the other. It is not the authors' intention to review and rectify this mass of stratigraphic nomenclature based on relatively brief study of subsurface information in the limited area of two 7½-minute quadrangles, but rather to give the reader a feeling for the general lithologic nature of this thick sedimentary sequence.

The clastic sequence overlying the Tully Formation up to the main body of red beds is considered basically marine in origin, and has been called the "Upper Devonian marine beds." The red-bed sequence has been called the Catskill Formation in the southern half of the Penfield 15-minute quadrangle (Edmunds and Berg, 1971, p. 11). The cyclic nature of the sequence leading up to the main body of red beds produces some repetition of deeper water deposits as well as a few early red-bed units. If the Catskill Formation were to be defined on the basis of the first appearance of red coloration, the base of the formation would be very tenuous and arbitrary.

Genetic Considerations

A number of fine papers regarding the general nature of Middle and Upper Devonian and some Mississippian stratigraphy in Pennsylvania are contained in Shepps (1963). Fettke (1941, p. 48) concisely summarized some of the broad problems surrounding the Upper Devonian in western Pennsylvania. Kelley (1967, p. 9), in his work on the Red Valley Sandstone of the Upper Devonian farther to the west, has presented a clear picture of dominant sedimentary processes that may well apply to laterally equivalent deposits in the Sabula-Penfield area.

The Upper Devonian sediments above the Tully Formation generally reflect continuing uplift in the source area along with continuing subsidence in the geosyncline. Paleoclimatic effects may be inferred as well, particularly in regard to the red-bed portions of the section. Cyclicity of deposition has complicated the general nature of the sequence. The causes of this cyclicity remain a question, but probably include lateral switching of depositional environments related to deltaic complexes, or periodic increases in orogenic activity, or a combination of both causes.

General upward coarsening characterizes the total section above the Tully. This is probably a reflection of the advance of increasingly shallow environments of deposition. These environments likely include in general upward succession: 1) open marine (basinal), 2) prodeltaic, and 3) deltaic (delta front, beach and bar, channel, bay and mudflat, etc.).

Lithologic Characteristics and Thickness

The lower 300 to 500 feet of the section is brownish-black to dark-gray, slightly calcareous clay shale that is often pyritic, micaceous, and fossiliferous.

The overlying 500 to 800 feet includes interbedded clay shale and silt shale; generally, clay shale is more dominant. These shales are usually medium dark gray, but some are brownish black. They are micaceous, fossiliferous, pyritic, and slightly calcareous.

Overlying the interbedded shales is a long sequence, about 2200 feet thick, that includes medium-dark-gray siltstone with brownish-black shale interbeds. This thick section, dominated by siltstone, is calcareous, micaceous, and fossiliferous.

The remainder of the Upper Devonian sequence up to the main red-bed section is interbedded sandstone, siltstone, and shale. It is about 1500 feet thick. Sandstones and siltstones appear to dominate and are medium light gray to brownish gray, quite fossiliferous in parts (crinoids, bryozoans, ostracodes, brachiopods), calcareous, and micaceous. Sporadic red beds and sandy limestones occur; the red beds appear in about the upper 500 feet.

Red beds comprise the upper 300 to 400 feet of Upper Devonian strata and are usually recorded in drilling logs as the "red rock." This red-bed sequence is generally clay shale with claystone but may be siltstone. Cuttings have even been recorded in one well (Ca5) as dominantly nonred sandstone (Plate 4). (The driller's log of the well at Ca5 shows a long section of "red rock," so it must be assumed that the cuttings became bleached by the time they were logged.) Some sporadic green zones occur, along with calcareous zones and some thin limestones. This red-bed section has apparently thinned from about 1300 feet in eastern Clearfield County.

The total thickness of Upper Devonian sediments overlying the Tully Formation, up to and including the Catskill red beds, amounts to an average of about 5200 feet in this report area.

Nature of Devonian-Mississippian Stratigraphic Boundary

The Devonian-Mississippian boundary is arbitrarily drawn at the top of the main red-bed sequence (Plates 2, 3, and 4). This boundary was also used in the southern part of the Penfield 15-minute quadrangle. Undoubtedly there may be some paleontologic evidence for placing the top of the Devonian higher, within what we call "Pocono" Formation. It is the authors' opinion that the Devonian-Mississippian time boundary is within a transition and is not marked by a lithostratigraphic break. Rare plant fossils (*Rhacophyton* sp.) collected by Dr. J. D. Grierson from surface exposures of the Pocono Formation in this area have previously been reported only from Upper Devonian rocks. However, most plant fossils from surface exposures are Mississippian. The authors have identified marine fossils in the Pocono as early Mississippian. Further work on the paleontology is clearly necessary. In some drilling records, up to 200 feet of the section over the main red-bed sequence is questionably correlated with the Devonian Conewango Formation.

Some drilling records have been used to illustrate the nature and stratigraphic relations of the upper part of the Upper Devonian and Mississippian strata in Plates 2, 3, and 4. In addition to their correlation value, these diagrams have been made to establish the reliability of the major red-bed sequence (Catskill) as a structural datum. (See the section on "Structural Geology" in this report.) Some geologists may consider the occurrence of red coloration as too sporadic to be of any value either for stratigraphic correlations or for determining structure. The authors feel that the top of the major red-bed sequence (although sporadic in a few records) is broadly correlative within the confines of the Sabula and Penfield quadrangles; that line of correlation is shown on Plates 2, 3, and 4.

Red coloration is being relied on here based on the belief that, at least within this report area, the mineralogy of the now red colored sediments may well reflect a tectonic or paleoclimatic event. Whether or not the red pigment is detrital or diagenetic, there is a major body of red strata that occupies a definite position in the stratigraphic sequence. The authors believe that the geologic factors causing red coloration in the main body of Catskill red beds represent an event of widespread significance over the Sabula-Penfield area. The same factors recurred, as indicated by the presence of red beds in the Pocono Formation (Plates 3 and 4), but not in the same magnitude as during the Late Devonian.

Mississippian Strata

As previously noted, the Devonian-Mississippian boundary is arbitrarily placed at the top of the major red-bed sequence. Succeeding strata of the overlying Pocono Formation represent continued deposition of a multiplicity of deltaic sediments and delta-related sediments.

The Pocono Formation ranges from slightly more than 800 to about 450 feet thick in this report area (Plates 2, 3, and 4). The authors believe that general northward thinning is due primarily to beveling of the Pocono beneath the Mississippian-Pennsylvanian unconformity. Some thickness variation of this formation may well be due to lateral facies gradation with the subjacent Catskill red beds.

The Pocono consists of interbedded sandstone, siltstone, silt shale, and clay shale. The sandstones are normally light gray, micaceous, calcareous, occasionally pyritic, and frequently bear brachiopods and crinoids. The siltstones and shales are medium gray to brownish gray with sporadic grayish-red and greenish-gray units throughout the section (Plates 3 and 4). Plant fossils are fairly abundant, especially in the shales; some carbonaceous stringers occur.

In the central and southern portions of this report area, a fairly persistent sequence of interbedded red, green, and gray siltstones and shales about 200 feet thick occurs near the top of the Pocono Formation. This was delineated as a separate, middle member of the Pocono in the southern half of the Penfield 15-minute quadrangle (Edmunds and Berg, 1971, p. 11). That member, often referred to as the "Patton" red beds, is cut out toward the north (Plate 4) below the Mississippian-Pennsylvanian unconformity.

The upper member (Burgoon Sandstone) of the Pocono Formation, described in the southern Penfield report (Edmunds and Berg, 1971), is probably also cut out toward the north by post-Mississippian erosion. Some of the Burgoon Member (Plate 1) is mapped in the southeastern part of the Penfield 7½-minute quadrangle. The general lithology and stratigraphic extent of this upper member are shown on Plates 3 and 4. The lower boundary of Burgoon sediments is affected by the sporadic nature of the "Patton" red beds and is therefore arbitrary. The possibility of lateral facies change between Burgoon and "Patton" should not be dismissed.

What Edmunds and Berg (1971) described as the "lower sequence" of the Pocono Formation (below the "Patton" Member) makes up the bulk of Mississippian strata in this report area.

SURFACE STRATIGRAPHY

Mississippian Strata

Pocono Formation

As in the southern Penfield area, the Pocono Formation is informally divisible into three units: the upper Burgoon Sandstone; the middle red, green, and gray sequence referred to as "Patton"; and the lower complex of sandstones, siltstones, and shales. The subsurface information that the authors have compiled indicates a regional unconformity between the Mississippian and Pennsylvanian rocks; pre-Pennsylvanian erosion apparently removed the Burgoon Sandstone and "Patton" red beds toward the north across the Sabula-Penfield area.

In the southeastern portion of this report area, the Burgoon is about 120 feet thick. The middle "Patton" red-bed section, although sporadic in subsurface records, appears to be on the order of 100 to 200 feet thick. The lower complex is about 500 to 600 feet thick, depending both on where the base of the "Patton" red beds is placed and where the top of the Catskill red beds is placed.

Pocono Formation rocks are exposed at the surface down to within about 250 feet above the Catskill red beds. The lowest actual outcrop is at Ca20 on the southeastern flank of Boone Mountain anticline, where a gas well was spudded in very thin bedded, light-brown to light-olive-gray sandstone, siltstone, and silt shale. Some bedding planes show intense burrowing with worm trails whereas others display abundant plant fragments and debris. On the northwestern flank of Boone Mountain anticline, at Ba2, about 15 feet of the lower part of the Pocono is exposed in a small pit. It is light-olive-gray, very fine grained, micaceous sandstone that is platy to very thin bedded. At the borrow area at Ba3, fine- to medium-grained sandstone and siltstone, silt shale, and clay shale were removed. The clay shale is moderate yellow green to light olive gray. Some shale-chip conglomerates occur in the sandstone.

Some scattered drill core pieces were found next to the new Brockway damsite at Ba4. Apparently the section just below the damsite includes medium-olive-gray, very fine grained, micaceous sandstone and some silt shale with abundant plant fragments. One piece of core was fine- to medium-grained sandstone with abundant productid brachiopod shells scattered throughout.

A water well drilled in the fall of 1969 at Aa4 penetrated 120 feet of the lower portion of the Pocono Formation. A detailed description of cuttings from that well is given in Appendix 1.

Other small outcrops and areas of float occur in the lower part of the Pocono, but the best exposures by far are in the new roadcuts along Pa. Route 153 going up Wilson Run and over Boone Mountain. Several detailed measured sections were made along Wilson Run, and the locations of these sections are shown in Figure 2. The detailed measured sections are described in Appendix 2. Examination of the Wilson Run roadcuts indicates that the lower complex of the Pocono Formation represents an interfingering of fossiliferous, offshore, shallow-marine sands with plant-bearing, nearshore, delta-distributary sands and silts. Some beach deposits may be represented in the sequence. In addition, sporadic red and green claystones and clay shales may represent tidal-mudflat environments in association with the deltaic lithologies.

In 1970, Dr. James D. Grierson of the State University of New York at Binghamton, New York, examined the section exposed in the cuts (sta-

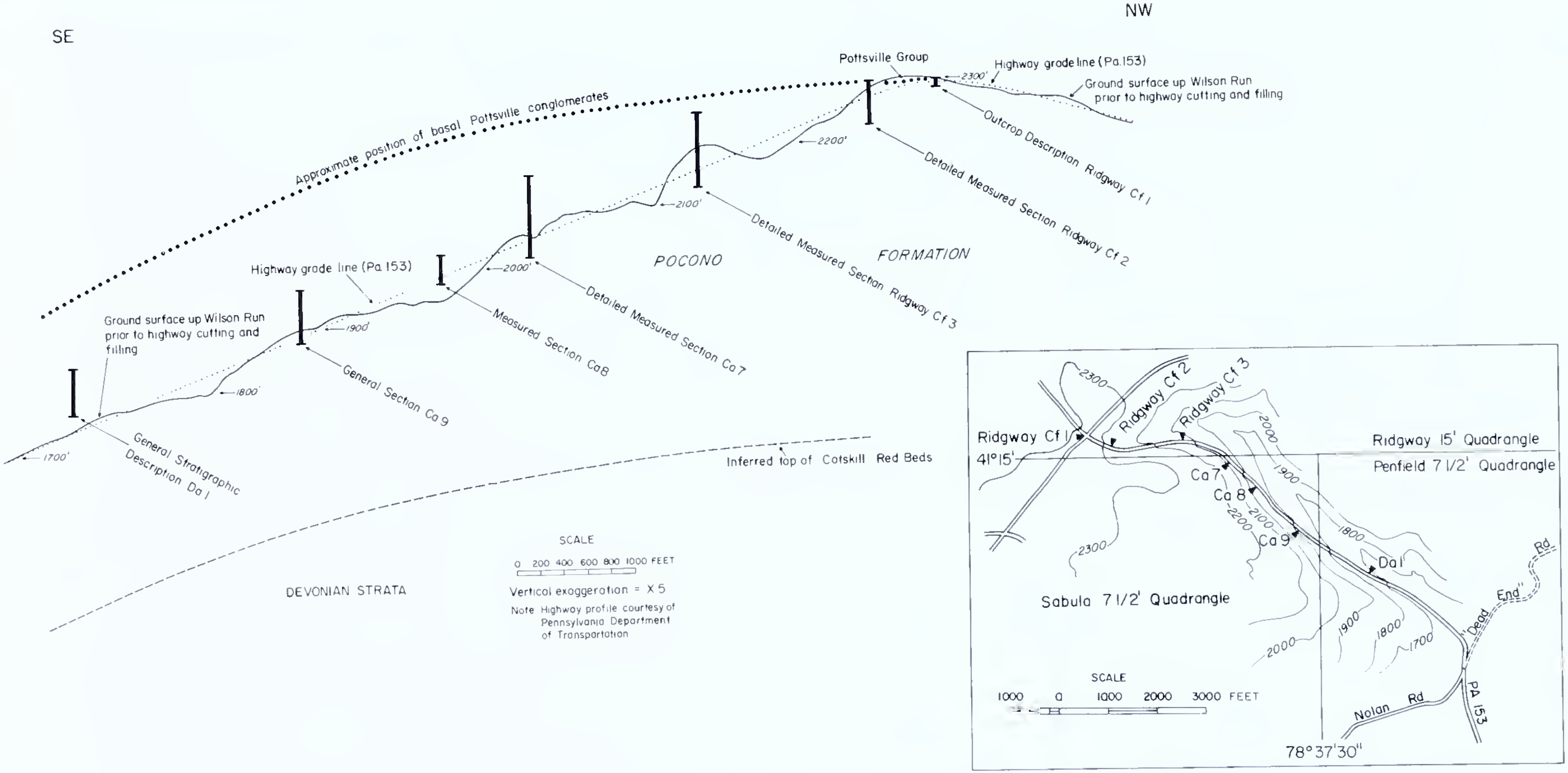
NW
SE
Pottsville Group
Highway grade line (Pa.153)
Ground surface up Wilson Run prior to highway cutting and filling
2300'
Outcrop Description Ridgway Cf 1
Detailed Measured Section Ridgway Cf 2
2200'
Approximate position of basal Pottsville conglomerates
2100'
Detailed Measured Section Ridgway Cf 3
POCONO
FORMATION
2000'
Detailed Measured Section Ca 7
Measured Section Ca8
Highway grade line (Pa 153)
1900'
General Section Ca 9
Ground surface up Wilson Run prior to highway cutting and filling
1800'
General Stratigraphic Description Da 1
1700'
Inferred top of Catskill Red Beds
DEVONIAN STRATA
SCALE
0 200 400 600 800 1000 FEET
Vertical exaggeration = X 5
Note Highway profile courtesy of Pennsylvania Department of Transportation
Ridgway Cf 1
Ridgway Cf 2
Ridgway Cf 3
2300
41°15'
Ridgway 15' Quadrangle
Penfield 7 1/2' Quadrangle
Ca 7
Ca 8
Ca 9
2200
2100
2000
1900
1800
1700
Da 1
Sabula 7 1/2' Quadrangle
Dead End Rd
PA 153
Nolan Rd
SCALE
1000 0 1000 2000 3000 FEET
78°37'30"

Figure 2. Lower Pocono exposures on the southeastern flank of Boone Mountain along Wilson Run. (See Appendix 2 for verbal descriptions of sections.)

tions Ridgway Cf2 and Ca7) along Pa. Route 153 at Wilson Run. His paleobotanical investigations indicate that fossil plants from those sections are most characteristic of zone 1 of Read and Mamay's (1964) Upper Paleozoic floral zones. This is the oldest Carboniferous floral zone and is considered to be Kinderhookian (earliest Mississippian) in age. Some specimens that were found in this section (*Rhacophyton* sp.) have previously been reported only from Upper Devonian rocks. Marine invertebrates found in the Wilson Run exposures appear to further support a Kinderhookian age for the lower complex of the Pocono Formation in this area. The diverse marine community includes the genera *Rhipidomella, Spirifer, Camarotoechia, Productus, Orbiculoidea,* and *Cypricardinia.*

Dr. Grierson states (personal commun., 1972) that he found *Adiantites spectabilis* Read and *Lepidodendropsis* sp. at station Ridgway Cf2. *A. spectabilis* occurs, according to Grierson, only in floral zone 1. At station Ridgway Ca7, a more diverse flora was found, including *Adiantites spectabilis, Lepidodendropsis* sp., and probable *Rhacophyton,* cf. *R. ceratangium* Andrews and Phillips. Grierson believes that the occurrence of *Rhacophyton* should be regarded as an extension of the stratigraphic range for this genus. Prior to this discovery, *Rhacophyton* was known only from the Upper Devonian of Belgium, Norway, and the United States.

Surface exposures of the middle "Patton" red-bed section and the upper Burgoon Sandstone are very poor. Mapping of the Burgoon in the southeastern portion (Plate 1) of this area has been done solely on the basis of aerial photographic interpretation and tracing of topographic benches. Extremely good exposures of these middle and upper Pocono units occur in the southern Penfield area, and lengthy lithologic descriptions are included in Edmunds and Berg (1971). Extensive paleobotanical work done in this part of the Pocono Formation by Professor William C. Darrah is included as an appendix in Edmunds and Berg (1971).

Mississippian-Pennsylvanian Unconformity

There is strong evidence that an unconformity exists between Mississippian and Pennsylvanian rocks in this area. Three basic lines of evidence point to the presence of a regional unconformity.

First, there is good physical evidence that basal Pennsylvanian sandstones and conglomerates rest on an erosion surface that is irregular, reflecting paleotopography on the Mississippian rocks. This irregular surface is shown in the line of drill holes on Plate 3. Paleotopographic irregularities on the Mississippian surface have been recognized by Lamb (1911, p. 105) in Ohio below the Sharon Conglomerate (basal Pottsville).

Carswell and Bennett (1963, p. 21) indicate that the Mississippian Hempfield Shale in the Neshannock 15-minute quadrangle in Pennsylvania is thinnest under channel sand deposits at the base of the Pennsylvanian Sharon Formation. The authors interpret the conglomeratic sandstones in the Boone Mountain area as the deposit of a braided-river system on an alluvial plain. The sudden vertical change from red, green, and gray delta-front sandstone and interdistributary mudstone of the Pocono to braided alluvial white and gray sandstone and conglomerate of the Pottsville is consistent with the presence of an unconformity, and indeed, appears to require one.

Second, the regional stratigraphic setting provides evidence for an unconformity. It is apparent that this unconformity has gradually moved down section at the expense of Mississippian strata in a northward direction across the central part of the state, eliminating the Loyalhanna-Mauch Chunk sequence, so that Pennsylvanian rocks lie directly on the Pocono Formation in the Penfield 15-minute quadrangle. At the southern boundary of this 15-minute quadrangle, the Pocono includes at least 300 feet of Burgoon Sandstone at the top; at the northern boundary (Boone Mountain area), the Burgoon is missing along with the underlying "Patton" red beds. On a broader scale, Fettke (1941, p. 49) describes the unconformity:

> A pronounced erosional unconformity at the contact of the Pennsylvanian and Mississippian systems bevels successively younger and younger southerly-dipping Mississippian strata in going from north to south across western Pennsylvania. In northern McKean County, Pottsville (Olean) sandstone rests upon the lower 65 feet of the Knapp formation, the lowest member of the Mississippian system; while in Fayette County, the Pottsville overlies the Mauch Chunk red shale, the highest member.

Some consideration should be given to the possibility that the Burgoon and "Patton" are missing due to nondeposition or facies change. However, if depositional processes from Mississippian through Pennsylvanian were uninterrupted, there would be no physical or paleobotanical break in the sequence. The authors believe that the conglomeratic sandstones in the Boone Mountain area correlate with those described by Ashburner (1880) as "Olean." L. D. Meckel's (1967) detailed sedimentological work on the Pottsville conglomerates (Olean-Sharon) strongly supports the conclusion that the conglomerates in the northern part of this report area are truly Early Pennsylvanian and were spread across a significant erosion surface developed on the Mississippian strata. The conglomeratic Pennsylvanian section is not developed in the southern part of the Sabula-Penfield area; the stratigraphic evidence for an unconformity in that region has received detailed treatment in Edmunds and Berg (1971). It seems possible that the thick Mercer flint clays were developed while the Pottsville (Olean) conglomerates were being deposited to the north.

Third, there is paleobotanical evidence for an unconformity. Fossil plants found in the roadcuts along Interstate Route 80 in the southern Penfield area (Edmunds and Berg, 1971) indicate floral zone 8 (middle Middle Pennsylvanian) resting directly and unconformably on floral zone 2 (Middle Mississippian). On Boone Mountain in this report area, the basal Pennsylvanian sandstones and conglomerates rest on rocks bearing fossil plants of floral zone 1 (Early Mississippian) as established by Dr. J. D. Grierson (personal commun.). If these basal Pennsylvanian sediments are correlative with the Olean and Sharon Conglomerates, then floral zone 6 would rest on zone 1. If the basal Pennsylvanian sediments on Boone Mountain are correlative with the Elliott Park Formation to the south, then floral zone 8 would rest on zone 1. Thus four, if not six, floral zones are missing. Regardless of the inexact paleobotanical dating of the basal Pennsylvanian on Boone Mountain, there is a break in the floral succession that points toward an unconformity. The conclusion that the conglomeratic sandstones are not Mississippian is based partly on the occurrence of numerous plant impressions on bedding planes that most closely resemble Pennsylvanian forms (decorticated ?*Sigillaria* sp.). This conclusion is simultaneously based on the regional stratigraphic framework outlined above.

In summary, the authors conclude that the Mississippian and Pennsylvanian rocks in this report area are separated by an unconformity of widespread significance. The existence of this unconformity is based on three interdependent lines of evidence, including physical criteria, regional stratigraphic framework, and paleobotanical findings. Further study of the conglomerates north of this report area along with investigation of the paleontology of underlying Mississippian rocks may more clearly define the unconformity and further beveling of the Pocono Formation to the north.

Pennsylvanian Strata

Sabula Drill Hole

The most detailed description of Pennsylvanian rocks in this area is the log of the core drilled in the Sabula quadrangle by the Pennsylvania Geological Survey in June of 1969. The drill hole is located at Cb3 and penetrates 716 feet of the Pennsylvanian, including all of the Allegheny Group, part of the Conemaugh Group, and most of the Pottsville Group. The description is given in Appendix 3 of this report. Another detailed record of Pennsylvanian rocks from this area is the log of the Pennsylvania Railroad drill core, which was drilled in June of 1958 and was located at Bc1. The hole penetrated more than 578 feet of strata, including part of the Conemaugh Group, all of the Allegheny Group, and the upper part of the Pottsville Group. This core was described by V. C. Shepps and E. G. Williams, and their description is given in Appendix 4 of this report. Readers are referred to these appendices as well as to the long sections and other long drilling records shown on Plate 5.

Pennsylvanian Stratigraphic Terminology

The terminology used in this report for stratigraphic units within the Pottsville and Allegheny Groups is that proposed by Edmunds (1969) for Clearfield County. His terminology and formational boundaries are based on key beds rather than on lithologic homogeneity. Since there is little or no information on the key Mercer coal beds and their stratigraphic framework, it has not been possible to carry his Pottsville terminology across the Punxsutawney-Caledonia syncline. However, the Allegheny formational names still appear to be justifiable for mapping purposes within the limits of this report area. In many instances, identification of the key coal beds is necessarily subjective.

Pottsville Group

General. In the southeastern portion of the Sabula-Penfield area, following the mapping of Edmunds and Berg (1971) just to the south, the Pottsville Group is subdivided into the Elliott Park and overlying Curwensville Formations. This subdivision is unrecognizable in the vicinity of Boone Mountain because there is no information on the key Mercer coal beds and their correlation. It is mapped in that area as Pottsville Group undivided.

Elliott Park Formation. The Elliott Park Formation includes all the rocks above the Mississippian-Pennsylvanian unconformity up to the base of the lowest Mercer underclay. This formation has been defined by Edmunds (1969, p. 17) in the Elliott Park quadrangle. Following this definition, the portion of the Sabula drill hole below 664.5 feet would be included in the Elliott Park Formation. (The bottom of the Pottsville was not penetrated in this drill hole.) The identifications of Mercer coals in the Sabula drill hole are tentative and subject to change. They do not serve as the basis of a complete stratigraphic framework.

Exposures in the southeastern portion of the Sabula-Penfield area are very poor and sparse. The mapping of the Elliott Park Formation is based on stratigraphic intervals established by Edmunds and Berg (1971) and Glover (1970), and on aerial photographic interpretation of topographic benches.

The Elliott Park is dominantly sandstone which has been correlated with the Upper Connoquenessing Sandstone and related lithologies below the Lower Mercer clay (Edmunds, 1969, p. 17), and ranges up to 65 feet thick. Large float blocks were frequently seen near outcrops in this area, particularly at Fb20 (Figure 3) and Fb21. The sandstone is very similar to the underlying Burgoon Sandstone. It is fine- to medium-grained, very light to light-gray or light-brownish-gray, quartzose sandstone. Some rootworking occurs near the top. Bedding thickness varies from 1 inch up to about 2 feet. The unit displays trough crossbedding and internal channeling. Below the sandstone, the Quakertown(?) coal may be sporadically developed; it ranges from 0 to 0.5 feet thick in the southern Penfield area. Edmunds and Berg (1971, p. 22) describe a localized unit (up to 6 feet thick) below the coal that consists of pinkish interbedded sandstone and clay shale.

Curwensville Formation. The Curwensville Formation includes the rocks from the base of the lowest Mercer underclay to the base of the Clarion no. 1 coal as defined by Edmunds (1969, p. 17). This formation includes the section from 570.3 to 664.5 feet in the Sabula drill hole. Designation of the Clarion no. 1 coal horizon in the Sabula drill hole is difficult because there are several closely spaced, thin coaly zones with underclay horizons that could correlate with the Clarion no. 1 coal. The authors have arbitrarily chosen the lowest coaly zone (with its well-developed

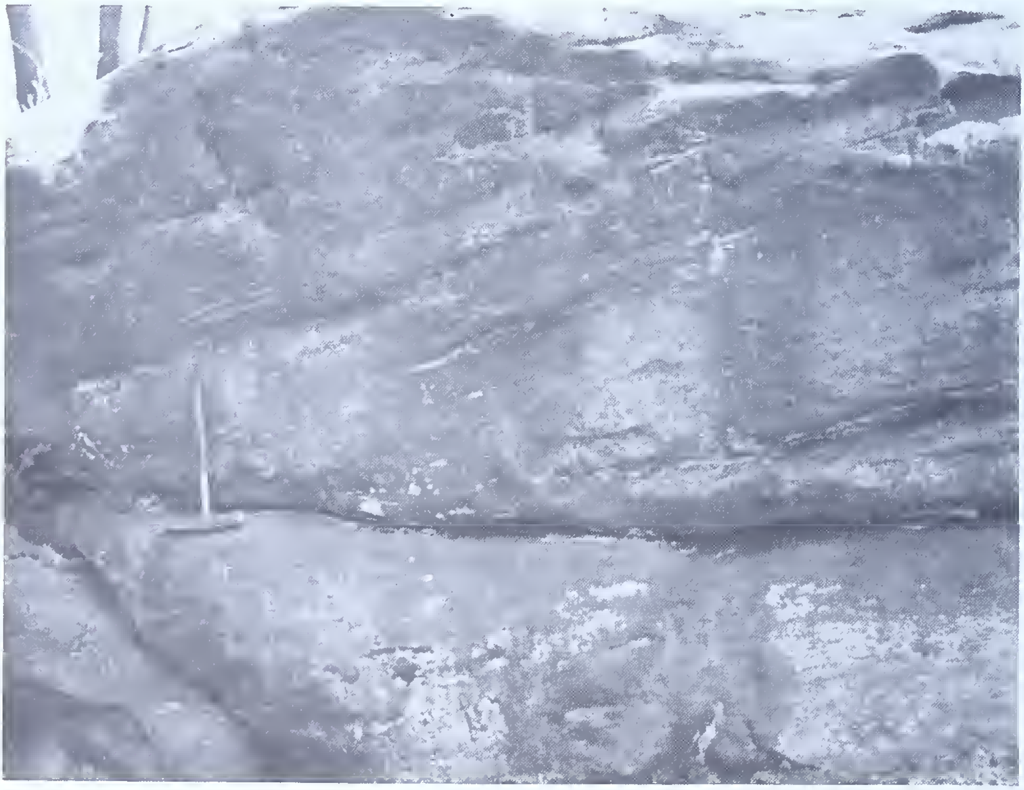

Figure 3. Crossbedding in Upper Connoquenessing Sandstone exposed on eastern shore of Parker Dam Lake at station Fb20.

underclay horizon) at 570.3 feet as the Clarion no. 1 coal. The Pennsylvania Railroad drill hole penetrated only the top of the Curwensville Formation. This formation is highly variable in thickness and lithologic character in the southern half of the Penfield 15-minute quadrangle (Edmunds and Berg, 1971, p. 23). As demonstrated in the Sabula drill hole, the formation is at least equally complex in lithologic aspect, but the paucity of other information makes it impossible to describe its variation over the Sabula and Penfield quadrangles. It is fairly clear from the Sabula drill hole that there are two coal groups in the Curwensville as in the quadrangles to the south and southeast, but the extent of splitting here is not known. The formation as mapped in the southeastern portion of this report area is, on the average, 80 feet thick. Actual mapping of the formation is based on aerial photographic interpretation as well as extrapolation of data from the southern Penfield area and the southern Clearfield area. The Homewood Sandstone Member of the Curwensville appears to be well developed and probably ranges up to 25 feet thick in the southeastern portion of this report area. The Homewood (Figure 4) is a quartzose sandstone ranging from medium to very coarse grained with a sericite matrix and considerable authigenic silica

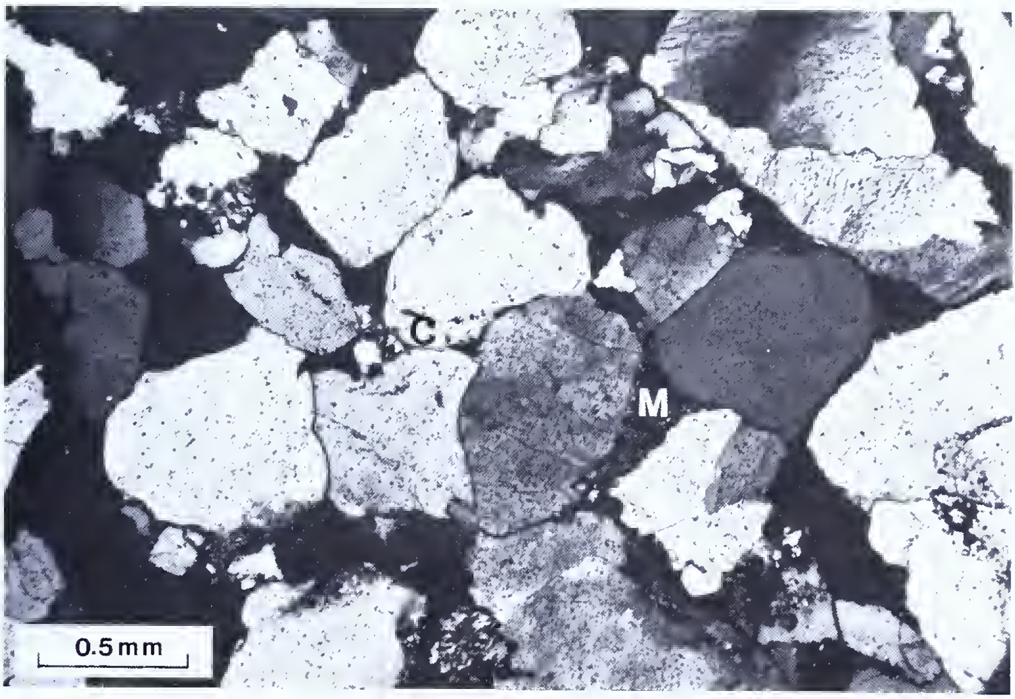

Figure 4. Photomicrograph of thin section of Homewood Sandstone from Panther Rocks area at station Clearfield Ac1, showing nature of quartz framework, sericite matrix (M), and authigenic silica cement (C). Crossed nicols.

cement. Tabular crossbedding is apparently a dominant type of stratification in the Homewood Member.

Pottsville Group Undivided. Over the Boone Mountain anticline region, the authors have been unable to locate key Mercer coals and therefore cannot differentiate the Elliott Park and Curwensville Formations. The thickness of the undifferentiated Pottsville Group in the Boone Mountain area is estimated to range from about 150 feet to about 200 feet, but nowhere is the entire group penetrated in the drilling records from Boone Mountain, as none of the drilling started above the top of the group.

In the Sabula drill hole (supplemented by drilling records from the adjacent gas well), the Pottsville Group is 160 feet thick. The basal conglomeratic sandstone portion is about 56 feet thick. The Quakertown coal horizon is not identifiable in this drill hole. Thin-section analysis of this sandstone (Figure 5) indicates that it is an immature to submature subphyllarenite (classification of Folk, 1968). The results of the analysis are as follows:

Thin section no. 74aDH-25

Depth in Sabula drill hole—683.3 feet

Estimated grain size range—0.1 to 2.0 mm

Average grain size—approx. 0.6 mm

Composition, based on 500 point-count percent

Quartz*	78.9%
Chert fragments	0.2%
Metamorphic rock fragments	3.5%
Coarse mica (>0.03 mm)	2.3%
Zircon	Trace
Kaolinite matrix	2.3%
Sericite or illite matrix	2.5%
Sericite-chert composite binder	6.4%
Authigenic silica cement	3.1%
Voids and unidentified	0.8%

* Includes strained and unstrained quartz, polycrystalline quartz, and stretched metamorphic quartz.

The character of the group has changed with the development of very coarse, quartzose conglomerates in the basal 60 to 80 feet, presumably below the Quakertown coal horizon. Lack of exposure and drilling information in this area prevents discussion of the group above the basal conglomeratic sandstones. The best physical description of the upper part of the group nearest the Boone Mountain area is in the Sabula drill hole log. The conglomerates clearly overlie Mississippian strata, and are the same as the basal Pottsville "Olean" conglomerates described by

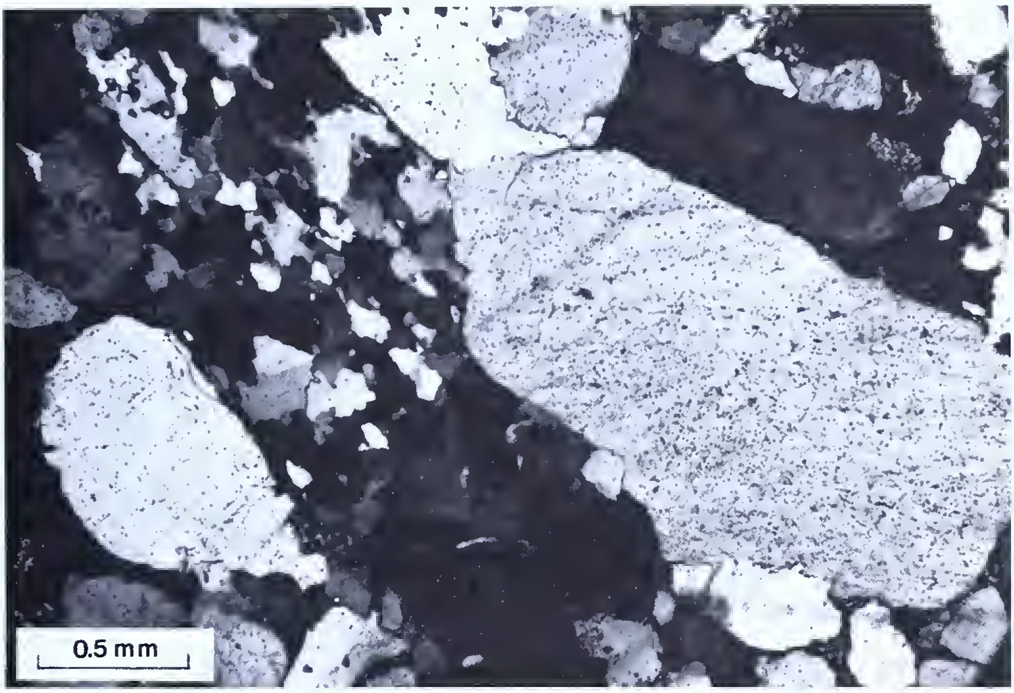

Figure 5. Photomicrograph of thin section of Pottsville subphyllarenite from 683.3 feet in the Sabula drill hole at station Cb3, showing various quartz types and small pockets of clay matrix. Crossed nicols.

C. A. Ashburner of the Second Pennsylvania Geological Survey. In differentiating the Pennsylvanian conglomerates from Mississippian ones, he states (1880, p. 57):

> At the bottom of the Coal Measures we find a hard, massive, coarse-grained sandstone and conglomerate immediately overlying the green, gray and olive sandstones and shales which characterize the interval between the Olean and Sub-Olean conglomerates.
>
> The pebbles in the upper conglomerate are invariably round or prolate spheroids (egg shaped) consequently this rock cannot be mistaken for the lower or SUB-OLEAN CONGLOMERATE in which the pebbles are flat or oblate spheroids having the shape of a flattened orange.

Both Ashburner's and the authors' observations tend to overrule the possibility of a Mississippian age for this conglomerate.

It is important to note here that several specimens of large plant impressions were observed and collected (Figure 6) in this very coarse grained sandstone and conglomerate. Although preservation is poor and some paleobotanical speculations may be possible, these impressions are probably *Sigillaria,* a common genus in the Pennsylvanian, but rare in the Mississippian. These impressions bear no resemblance to plant trunks or branches that the authors have seen in the underlying Pocono sediments.

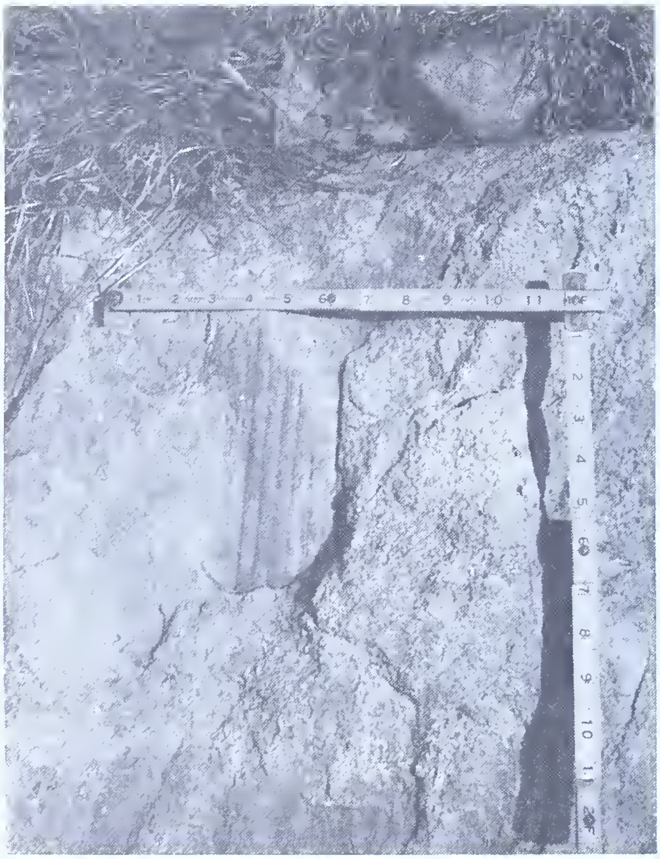

Figure 6. Plant impression in Pottsville sandstone from Boone Mountain at station Ca2.

The basal Pottsville conglomerate may be seen at many places over the Boone Mountain anticline, mostly as large float blocks, especially where excavations for natural gas transmission pipelines have unearthed large boulders as at Ba13 (Figure 7). Other good areas of heavy conglomeratic float occur at Ba9, Ba11, Ba15, Ba17, Ba20, Ba21, Ba23, Ca2, Ca3, Ca6, Ca13, Ca14, Ca15, Ca17, and above the section at Ridgway Cf2. The best exposure of the basal Pottsville is at Ca18, above Pete Buck Hollow, where a "rock city" has developed in the massive sandstones (Figure 8). Here, the Pottsville is medium grained to very coarse grained with sporadic lenses of granule and pebble conglomerate. Some beds are parallel bedded with no clear crossbedding. The sandstone is poorly sorted; colors are moderate orange pink and white, weathering to light gray and pale reddish brown in places. Bedding varies from 3 inches to 1 foot, but the sandstone body remains intact as huge, massive blocks. The sand grains are generally angular to subangular and are moderately sorted. There are about equal amounts of clay matrix and silica cement. Some vague ripple bedding occurs near the top of the outcrop.

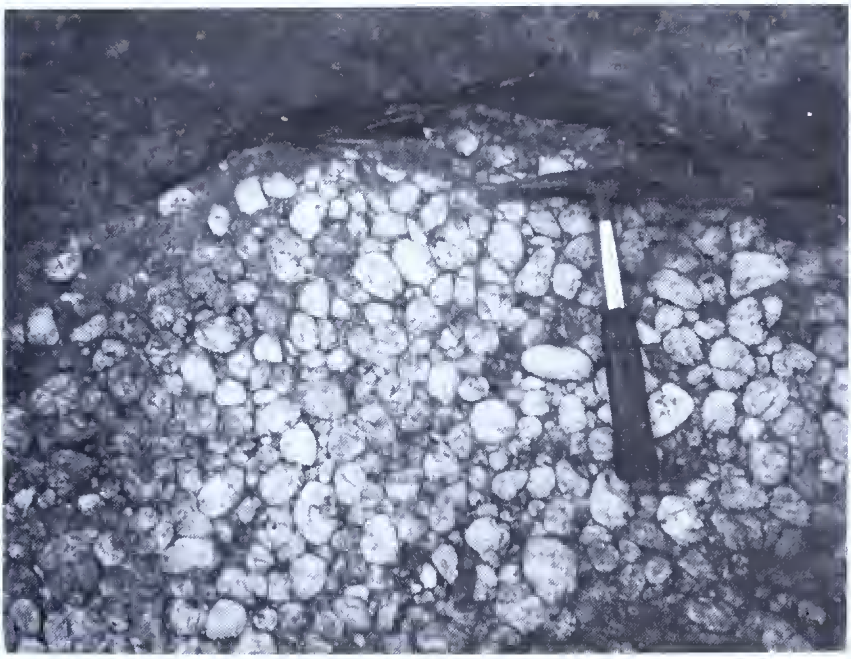

Figure 7. Quartz-pebble conglomerate in Pottsville Group on Boone Mountain at station Ba13.

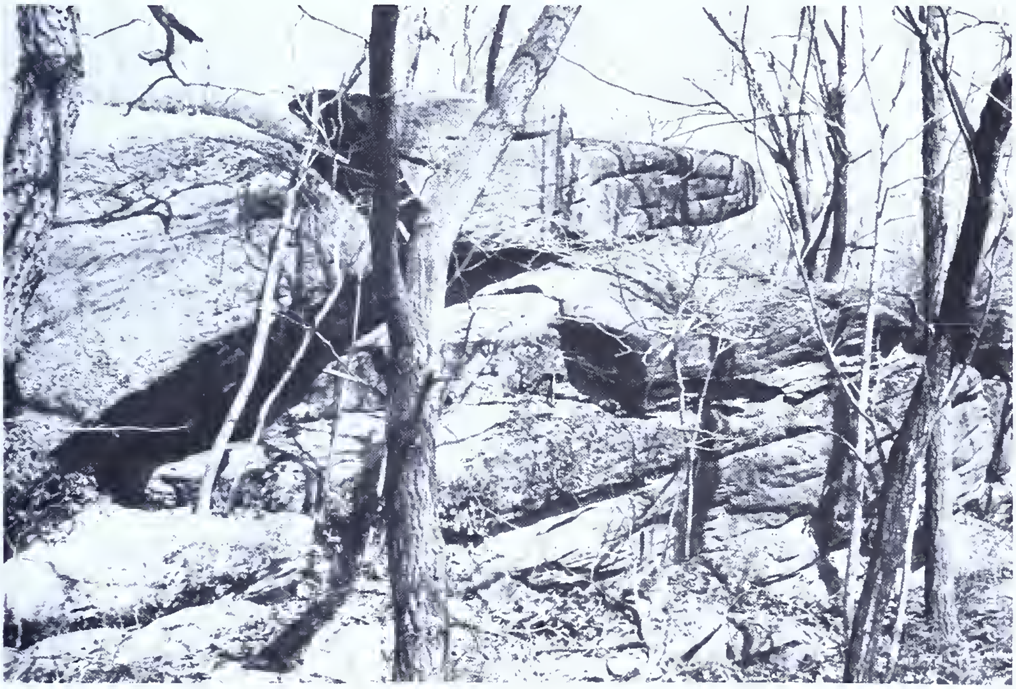

Figure 8. Massive Pottsville sandstone above Pete Buck Hollow at station Ca18. Hammer in center of photograph gives scale.

Another "rock city" that has developed in these Pottsville conglomerates may be found at Da38 (Figure 9). Here the sandstone is coarse grained with a few very coarse grains and with lenses of granule and pebble conglomerate. The unit is very light gray to white with occasional brownish streaks, is very porous and poorly cemented, and exhibits massive bedding, mostly 6 to 8 feet thick.

The majority of pebbles and cobbles in the basal Pottsville conglomerate are rounded to well rounded, and usually display moderate sphericity. Some pebbles are oblong. The pebbles are dominantly very light gray to white metamorphic quartzite (Figures 10 and 11), but the authors have found rare pebbles of hard, grayish-black schist and badly weathered medium-gray limestone.

Allegheny Group

General. The Allegheny Group, subdivided into five formations, is the most economically important stratigraphic interval in the Sabula-Penfield area, containing at least five minable coal seams. The Lower Kittanning no. 3 coal is the most widely mined.

The group varies from 310 to 330 feet thick. However, because of the uncertainty in correlating the Lower and Upper Freeport coals in the

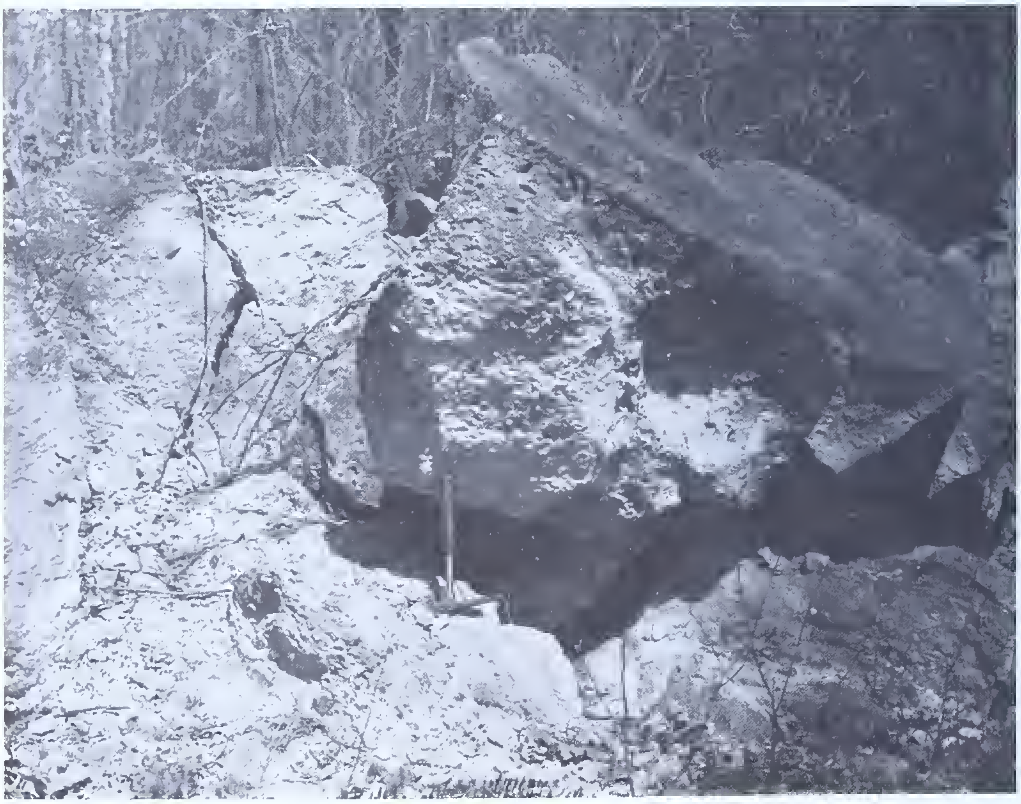

Figure 9. Massive Pottsville conglomerate at station Da38.

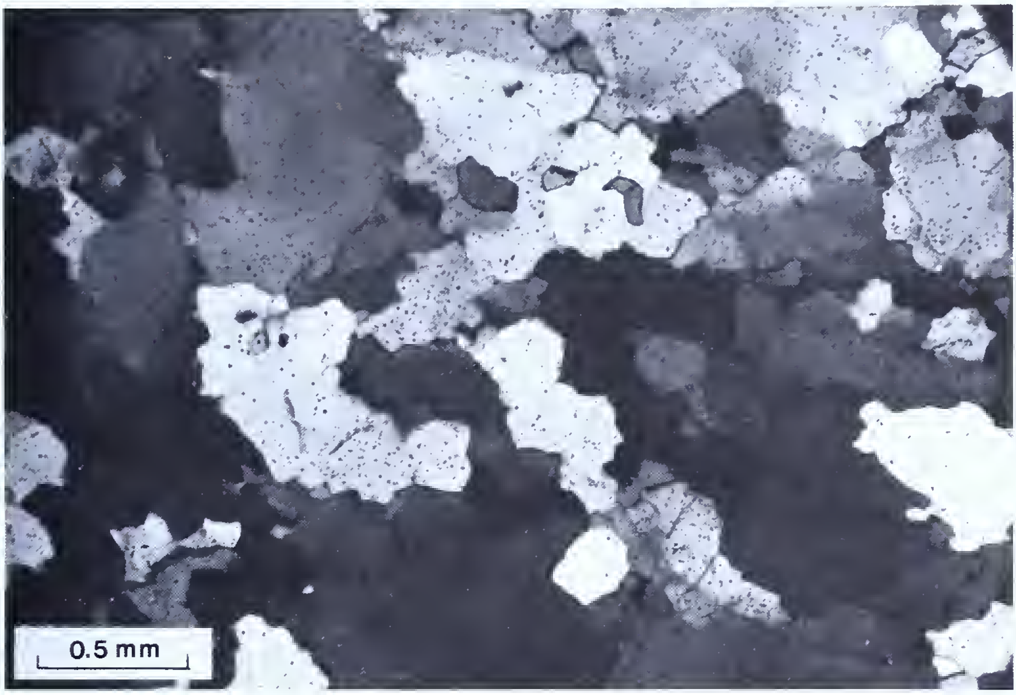

Figure 10. Photomicrograph of thin section of metamorphic quartzite pebble from the basal Pottsville conglomerate on Boone Mountain at station Ba13. Crossed nicols.

drill records at Bc1, Bc2, and Cc2 (Plate 5), and considering the possible existence of a local coal between the Mahoning and Upper Freeport coal horizons, the total thickness of the Allegheny Group may reach 350 feet. The sedimentological aspects of this possible apparent thickening are unknown, and, considering the limited number of records available, any correlation of those units must be regarded as tentative. Part of the thickness variation is due to Pennsylvanian-age erosion at the top of the group with a consequent local disconformity in places beneath the Lower Mahoning Sandstone of the Conemaugh Group. Another cause for variation in the thickness of the Allegheny is internal thinning and thickening of the individual formations.

Clearfield Creek Formation. The Clearfield Creek Formation includes all the strata from the base of the Clarion no. 1 coal up to the base of the Lower Kittanning no. 1 coal. This is the most poorly exposed formation within the Allegheny Group; on that account, very little can be said about the unit over the whole of the Sabula-Penfield area.

In the Sabula drill hole, the section from about 495.0 feet to 570.4 feet constitutes the Clearfield Creek Formation. The Lower Kittanning no. 1 coal is poorly represented in the drill hole and may be lacking. Its horizon is arbitrarily picked at about 495.0 feet, clearly below the thick underclay complex developed beneath the Lower Kittanning no. 3 coal.

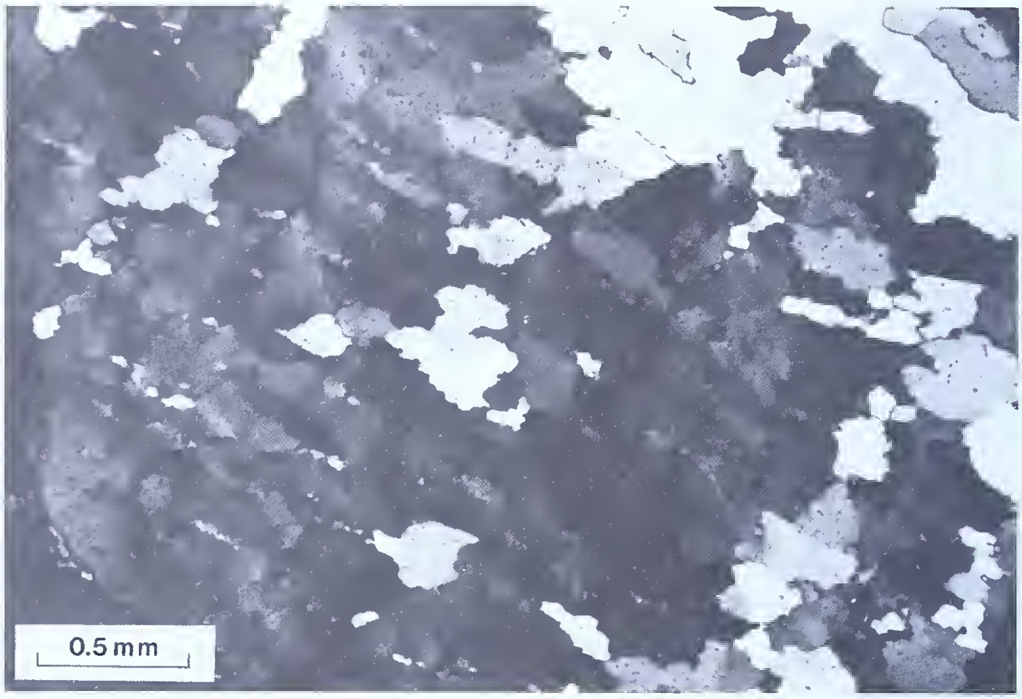

Figure 11. Photomicrograph of thin section of strongly deformed, recrystallized metamorphic quartzite pebble from the basal Pottsville conglomerate on Boone Mountain at station Ba13. Crossed nicols. Note crystal alignment and strongly sutured contacts.

The thickness of the Clearfield Creek is close to 75 feet in the Sabula drill hole. In the Pennsylvania Railroad drill hole (Appendix 4), the Lower Kittanning no. 1 coal is probably absent, although the coaly streaks in the sandstone that underlies the rather thick claystone developed below the Lower Kittanning no. 3 coal may represent this unit. Based on this consideration, the horizon of the Lower Kittanning no. 1 coal is arbitrarily picked at 507.0 feet. The base of the Clarion no. 1 coal is at 563.08 feet, making the thickness of the Clearfield Creek Formation about 56 feet in this hole.

The formation varies up to about 90 feet thick, depending on the vertical positions of the Clarion no. 1 and Lower Kittanning no. 1 coal horizons. The underclay sequence beneath the Lower Kittanning no. 3 coal is estimated to average about 20 feet in thickness.

The Vanport Limestone horizon, although encountered in the Sabula drill hole, was never observed in the Sabula-Penfield area in surface outcrop. Ashburner (Ashburner and Shaefer, 1885, p. 240-241) reports an outcrop of the "Ferriferous Limestone" (the Vanport) along Little Toby Creek in Snyder Township, Jefferson County, only a short distance from the Jefferson-Elk County line. This limestone bed also crops out in the hill east of Brockport. The authors could not locate any limestone outcrop along Toby Creek in this report area, but a few feet of fossiliferous Vanport Limestone does crop out upstream, about 1½ miles into the Ridgway 15-minute quadrangle.

A generalized sequence for the Clearfield Creek Formation is as follows (descending order):

Underclay (0 to 8 ft).
Kittanning Sandstone with disconformity at base (0 to 15 ft).
Fossiliferous clay shale and limestone sequence (Vanport Limestone) (up to 7 ft).
Shale and sand-silt laminite sequence (about 10 ft).
Clarion no. 3 coal horizon (0 ft to few in.).
Progaded sequence—carbonaceous shale, sand-silt laminite, to sandstone (up to 20 ft).
Clarion no. 2 coal (up to 0.7 ft).
Mixed underclay, sandstone, and carbonaceous shale sequence (up to 28 ft).
Clarion no. 1 coal horizon (up to 0.5 ft).

Only a sparse number of surface exposures of the Clearfield Creek are available in this area. They are located in the northwestern part of the Sabula quadrangle at Aa10, Aa12, and Aa13, and in the central part of the Sabula quadrangle at Bb8. At Aa12, only 8 feet of the Kittanning Sandstone is exposed; it is light-gray, micaceous, interbedded sand-silt laminite and sandstone, with common ripple bedding. The sandstone is very fine to fine grained and weathers to chippy and slabby fragments. Measured sections at Aa10, Aa13, and Bb8 are given in Appendix 5 (p. A43).

Millstone Run Formation. The rocks from the base of the Lower Kittanning no. 1 coal up to the base of the Middle Kittanning coal are included in the Millstone Run Formation. The section from 396.8 feet to about 495.0 feet in the Sabula drill hole constitutes the Millstone Run Formation. The Millstone Run Formation in the Pennsylvania Railroad drill hole includes the section from 418.25 feet to 507.0 feet, a thickness of approximately 89 feet. As mentioned before, the Lower Kittanning no. 1 coal horizon is picked below the thick underclay complex developed beneath the Lower Kittanning no. 3 coal. Although the Lower Kittanning no. 1 coal is usually poorly developed and exposed, the authors' experience (especially in the southern half of the Penfield 15-minute quadrangle) has been that this key bed is recognizable in drill holes or clear surface exposures below the thick underclay complex. The Lower Kittanning no. 1 split probably persists over the Sabula-Penfield area. At Ec5, the Lower Kittanning no. 1 coal was clearly exposed as a blossom beneath 20 to 24 feet of underclay.

This formation averages 70 to 80 feet in thickness. The Lower Kittanning no. 3 coal is the most extensively mined seam in this area (Plate 7).

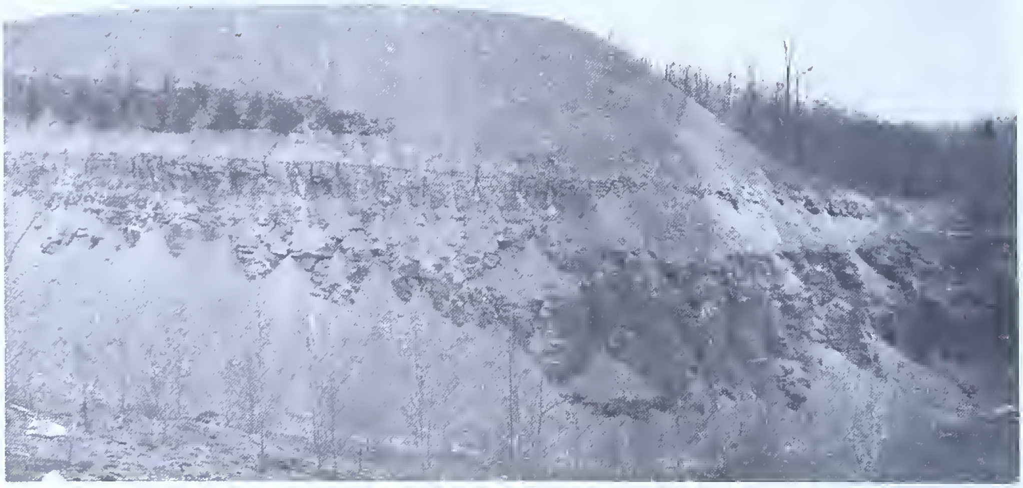

Figure 12. Exposure of the Millstone Run Formation in an abandoned strip mine at station Bb10. Dark shales exposed at upper left are overlying the Middle Kittanning coal horizon.

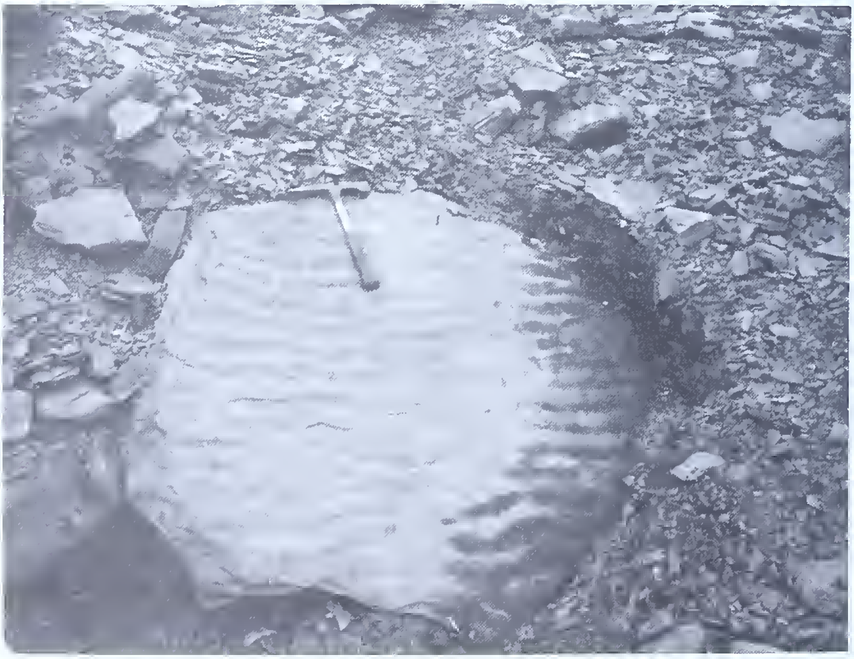

Figure 13. Asymmetrical ripple marks in the Millstone Run Formation at station Bb10, about 34 feet above the Lower Kittanning no. 3 coal.

A generalized sequence for the Millstone Run Formation with average unit thicknesses is as follows (descending order):

Rootworked claystone or siltstone (Middle Kittanning underclay horizon) (1 to 6 ft).
Interbedded silt shale and clay shale, sometimes with thin black shale near middle (Lower Kittanning no. 4 coal horizon?), sometimes with channel sandstone (Lower Worthington?) (up to 25 ft).
Fossiliferous marine siltstone or sandstone (0 to 2 ft).
Interbedded silt shale and sand-silt laminite or well-developed sandstone with disconformity at base (10 to 38 ft).
Fossiliferous marine black shale grading up through clay shale to silt shale to sand-silt laminite (6 to 23 ft).
Lower Kittanning no. 3 coal (1.4 to 3.6 ft).
Underclay complex (20 to 27 ft).
Lower Kittanning no. 1 coal (0 to 0.2 ft).

Plate 6 shows the general nature of the Millstone Run along the northwestern flank of the Punxsutawney-Caledonia syncline and in a line roughly perpendicular to the axis of the syncline.

Detailed lithologic descriptions of the Millstone Run Formation from the best exposures in strip-mine highwalls in this report area are given in Appendix 5 (p. A43-A50). Typical exposures of the Millstone Run are shown in Figures 12, 13, 14, and 15.

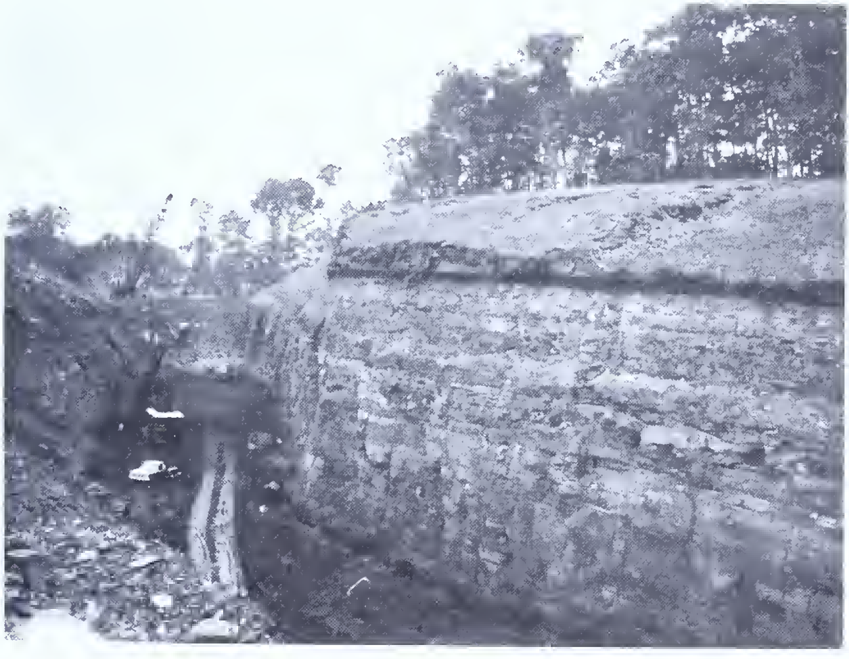

Figure 14. Millstone Run Formation at station Da2, near Middle Branch of Wilson Run. Lower Kittanning coal is being mined; Middle Kittanning coal is near top of highwall.

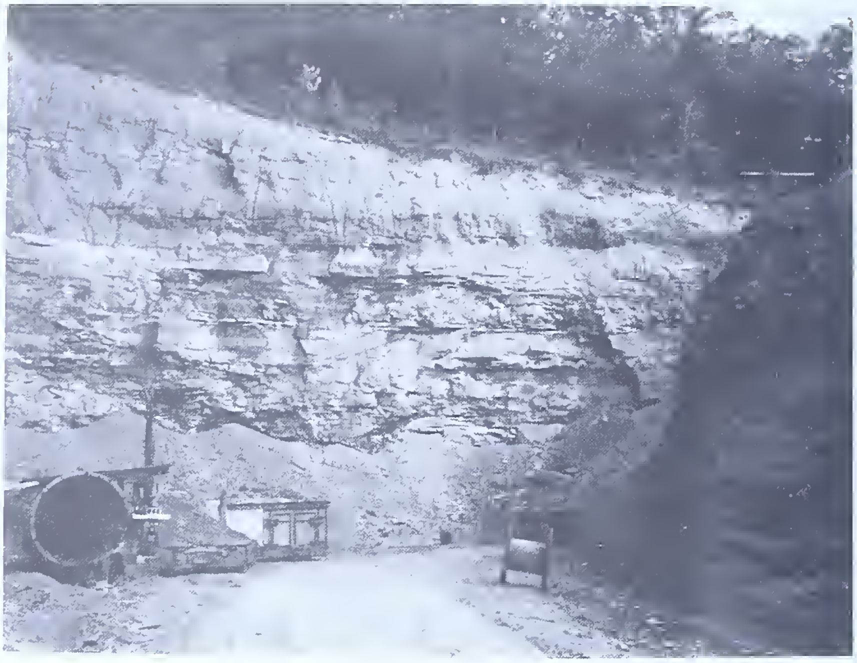

Figure 15. Millstone Run Formation at the Horning Run heading of the Lady Jane mine at station Fb2. The Middle Kittanning coal is exposed 32 feet above the mined seam (Lower Kittanning).

Mineral Springs Formation. The Mineral Springs Formation includes the strata from the base of the Middle Kittanning coal upward to the base of the Upper Kittanning coal. Both of these coals are generally laterally continuous; their identity as key beds is less in doubt than those in the underlying Pennsylvanian formations. Some confusion may arise if the Middle Kittanning coal is miscorrelated with the Lower Kittanning no. 4 coal horizon. There is also a possibility of misidentifying the Middle Kittanning no. 2 rider coal as the Upper Kittanning coal. (See drill hole Bc2, Plate 5.)

The Mineral Springs Formation averages 75 feet in thickness but thins eastward. The addition of one or two "rider" coals to the section appears to complicate the sequence in a westward direction. The Mineral Springs varies from about 50 feet to about 85 feet thick over the Sabula-Penfield area. The section from 396.8 feet to 317.2 feet in the Sabula drill hole constitutes the Mineral Springs Formation. In the Pennsylvania Railroad drill hole, the interval from 418.25 feet to 335.17 feet represents this formation. A generalized sequence for the Mineral Springs Formation is as follows (descending order):

> Rootworked claystone and siltstone, flint or semiflint clay, argillaceous limestone, and sand-silt laminite (Upper Kittanning underclay complex, Johnstown Limestone, and associated bioturbated laminites) (8 to 32 ft).

Coal (variously identified as Middle Kittanning no. 2 rider coal or "Luthersburg" coal) (0 to 0.4 ft).

Sandstone, sand-silt laminite, and silt-clay laminite with possible underclay horizon at top (Upper Worthington? sandstone) (0 to 18 ft).

Dark, fossiliferous marine clay shale, prograded upward to silt shale and silt-clay laminite with plant fossils (10 to 18 ft).

Coal, grading laterally to black shale, probably equivalent to the "black band" in the adjacent Luthersburg 7½-minute quadrangle to the south (Middle Kittanning no. 1 rider coal) (0.1 to 0.8 ft).

Interbedded sandstone, siltstone, sand-silt laminite, silt-clay laminite, grading downward to silt shale and clay shale with plant fossils throughout and an underclay horizon developed at the top (13 to 28 ft).

Carbonaceous black shale grading upward to dark silt shale with marine or brackish invertebrate fossils (0 to 15± ft).

Middle Kittanning coal (0.7 to 2.2 ft).

This general sequence is best defined by drill-hole information (Plate 5). The lithologic descriptions in the Sabula and Pennsylvania Railroad drill holes are the most detailed representation of this formation. Detailed descriptions of the lower part of the Mineral Springs Formation are recorded in sections described with the underlying Millstone Run Formation at Ab1, Bb10, Da2, Ridgway Ef1, Fb2, Ec4, and Ec6 (see measured sections under "Millstone Run Formation," Appendix 5, p. A45-A50). Other sections of the Mineral Springs were measured at Ac1, Eb53, and Ec12, and are included in Appendix 5, p. A50-A51.

No additional information on the Mineral Springs Formation is available. The Johnstown Limestone horizon is exposed in a number of places and is covered at greater length in the section on "Limestone" in the "Mineral Resources" portion of this atlas.

Laurel Run Formation. The Laurel Run Formation includes the rocks lying above the base of the Upper Kittanning coal and below the base of the Lower Freeport coal. These key beds appear to be widespread and normally persistent. In some instances, as in drill hole Bc1 (Plate 5), the Lower Freeport coal may interfinger with sandstone. As in the southern Penfield area, the Lower Freeport coal may be missing where eroded prior to deposition of overlying Pennsylvanian sandstones. The authors have also noted the possibility that both of these key beds may grade laterally (Plate 5) to black shales.

The Laurel Run varies from 27 to about 62 feet thick. The section from about 317.2 feet to 289.6 feet in the Sabula drill hole constitutes the Laurel Run Formation. In the Pennsylvania Railroad drill hole the Laurel Run Formation represents the interval from about 291.16 feet to 335.17 feet. A general sequence for this formation is as follows (descending order):

Rootworked, coaly shale and laminite to rootworked claystone with limestone nodules and sporadic limestone beds (Lower Freeport underclay) (0 to 6 ft).

Sand-silt laminite, sandstone, and siltstone, grading downward to olive clay shale (0 to 12 ft).
Carbonaceous clay shale (Upper Kittanning rider coal horizon?) (0 to 0.2 ft).
Rootworked claystone, possibly with some sporadic limestone (0 to 3 ft).
Sandstone (occasionally dominating entire section) (Freeport?) and sand-silt laminite, grading downward through olive siltstone and silt shale to olive clay shale with some calcareous siltstone; siderite or limonite concretions often occurring, plant fragments common (18 to 45 ft).
Dense, black clay shale, with rare plant fragments (0.2 to 11 ft).
Silty clay shale with plant fragments (0 to 5 ft).
Upper Kittanning coal (0 to 4.3 ft).

The measured sections at Aa9, Ac12, Ac10, Ab6, Ab5, Ab3, Bb23, Dc11, and Ea6 (Appendix 5, p. A51-A54) give the most detailed picture of Laurel Run lithologies visible in surface outcrop. The best exposures are concentrated in the Clear Run and Narrows Creek areas in the Sabula quadrangle.

Glen Richey Formation. The Glen Richey Formation includes those rocks lying above the base of the Lower Freeport coal and below the top of the Upper Freeport coal. Some stratigraphic complications occur with regard to the lateral extent of these key coal beds.

Along the southern edge of the Sabula-Penfield area, in the Punxsutawney-Caledonia syncline, the Upper Freeport coal is apparently occasionally missing as it was in the southern Penfield area. This is due to Pennsylvanian channel erosion and deposition of the Mahoning Sandstone of the Conemaugh Group. In some places in the southern Penfield area (Edmunds and Berg, 1971, p. 45), even the Lower Freeport coal was removed before Mahoning deposition; in this situation, the Glen Richey is entirely absent. The authors cannot demonstrate that the Glen Richey Formation is completely absent anywhere in this report area without more subsurface records, but that possibility should not be discounted.

It seems evident that the Lower Freeport coal may grade laterally into thin coaly zones (drill hole Bc1, Plate 5) in the Butler or Mahoning Sandstone complexes. Alternatively, it may be possible that the Lower Freeport coaly zones are associated with the uppermost portion of the Freeport Sandstone complex.

Both the Lower and Upper Freeport coals apparently may grade laterally to carbonaceous shales as in drill hole Bc2 (Plate 5).

There is a possibility of miscorrelation of the Upper Freeport coal with a Lower Freeport rider coal, especially in the north-central part of the Penfield 7½-minute quadrangle. If the coal tentatively identified as a Lower Freeport rider is actually the Upper Freeport coal, then an Upper Freeport rider coal is consequent.

The Glen Richey Formation varies from 38 to 70 feet thick where it is not affected by the Mahoning Sandstone complex. The section from

289.6 feet to 239.6 feet in the Sabula drill hole constitutes the Glen Richey Formation.

In the Pennsylvania Railroad drill hole (Plate 5), it is difficult to pick the position of the Upper Freeport coal, the top of which represents the top of the Glen Richey Formation. The rather thick coal found between 211.92 feet and 216.0 feet may be the Upper Freeport, or perhaps a local coal associated with the Mahoning Sandstone complex. As was commonly the case in the southern Penfield area (Edmunds and Berg, 1971), the Upper Freeport coal may have been cut out by stream channeling in this immediate area. If such was the case, the position of the horizon of the Upper Freeport coal may possibly be located at 251.17 feet in this hole. This position is immediately above a sandstone that contains some limy nodules. These limestone nodules quite probably represent the freshwater limestone that commonly underlies this coal. The writers favor placing the top of the Glen Richey Formation at 211.92 feet, making the formational thickness approximately 79 feet (Plate 5).

A generalized sequence for this formation in the Sabula-Penfield area is as follows (descending order):

Upper Freeport coal (0 to 3.8 ft).
Rootworked claystone and siltstone with some clay shale and possible hard clay (Upper Freeport underclay and possible associated Bolivar flint clay) (2 to 9 ft).
Interbedded claystone, silt shale, siltstone, silt-clay laminite, and sand-silt laminite bearing conchostracans, with occasional development of sandstone (Butler Sandstone?) (9 to 40 ft).
Carbonaceous clay shale, often with thin coal at base (Lower Freeport rider coal horizon) (0 to 4 ft).
Rootworked claystone and siltstone with occasional freshwater limestone (possibly confused with Upper Freeport limestone) (0 to 8 ft).
Interbedded silt shale, siltstone, sand-silt laminite, and sandstone with common plant fossils and some conchostracans; carbonaceous shale at base; rare carbonate zones (0.5 to 30 ft).
Lower Freeport coal (0 to 6 ft).

This formation is very poorly exposed in the Penfield 7½-minute quadrangle. As is the case with the underlying Laurel Run Formation, better exposures of the Glen Richey Formation occur in the Sabula quadrangle. Detailed sections were measured at Aa3, Ac11, Ac4, and Ac5; these are included in Appendix 5, p. A54-A57.

In the upper reaches of Narrows Creek, portions of the Glen Richey Formation are exposed fairly well at three sites. At Ab5, below the Treasure Lake dam, a coal blossom 31 feet above the Lower Freeport coal may be either the Upper Freeport coal or the Lower Freeport rider coal horizon. This is correlated with the Lower Freeport rider because of the short coal-to-coal interval; in addition, the underlying clastic sequence is very similar to the strata under the Lower Freeport rider in the Clear Run area. The detailed measured sections at Ab5, Bb24, and Bb16 (Appendix 5, p. A57-A58) will give some idea of the variability within, and the difficulty of mapping, the Glen Richey Formation.

Surface sections at Ea46 and Eb22 (Appendix 5, p. A58-A59) in the Glen Richey Formation, one including part of the overlying Conemaugh Group, were measured in the Penfield 7½-minute quadrangle. Both sections are similar to those measured in the Sabula quadrangle, especially with respect to dominance of fine, thin-bedded, olive-colored clastic sediments lacking marine fossils. These measured sections give some indication of the physical character of the Glen Richey in the vicinity of the village of Penfield.

Conemaugh Group

The Conemaugh Group, originally known as the Lower Barren Coal Measures, covers one fourth to one third of the Sabula and Penfield quadrangles. In contrast to the Allegheny Group, the coals in this group are commonly thin and are of little economic importance at present. The lower part of the Conemaugh (Glenshaw Formation of Flint, 1965) can be subdivided using several persistent marine fossil zones, which are actually better key beds for mapping purposes than the coal beds. To utilize these fossil zones, however, a separate, more regional biostratigraphic study of the zones must be carried out to establish paleoecologic, paleobiogeographic, and stratigraphic relationships of the faunal zones. Detailed taxonomic and population studies go hand-in-hand with this kind of biostratigraphic analysis. Such a study is clearly beyond the scope of this report. "On-the-spot" correlations of the fossil zones in the lower part of the Conemaugh are dangerous and often completely wrong. It is very easy, for example, to miscorrelate the Brush Creek and Cambridge-Pine Creek marine zones with each other; both zones bear very similar faunas that can be differentiated only by careful statistical analysis.

As defined by Platt (1875, p. 8), the Conemaugh Group includes the section between the top of the Upper Freeport coal and the base of the Pittsburgh coal. A maximum of about 630 feet of the Conemaugh exists in this report area. This includes all of the Glenshaw Formation and more than half of the Casselman Formation. These formations were defined by Flint (1965, p. 72), who divided the Conemaugh Group at the top of the Ames Limestone or marine bed. Portions of the Glenshaw are well exposed at several localities; the section from the Ames marine zone, marking the base of the Casselman Formation, up to the Federal Hill (Duquesne) coal is exposed above the Penn Central Railroad tunnel at Sabula (Cc6). The Ames marine zone and Harlem coal are well exposed along Pa. Route 255 at Bc3. Above that stratigraphic horizon, virtually no significant section is exposed. The unexposed part of the Casselman Formation is confined to the higher hills in the Punxsutawney-Caledonia syncline. The best information on the lower part of the Conemaugh was obtained from the Pennsylvania Railroad and Sabula drill holes. The sections from 239.6 feet up to the top of the Sabula drill hole and from 211.92 feet to the top of the Pennsylvania Railroad drill hole are in the Glenshaw Formation.

A generalized sequence for the Conemaugh Group from just above the Federal Hill (Duquesne) coal down to the top of the Upper Freeport coal is as follows:

Casselman Formation (incomplete)

Silt shale grading down to clay shale (25 ft+?).
Federal Hill (Duquesne) coal (3½ ft).
Underclay (11 ft).
Sandstone grading down to fissile laminites (Lower Grafton Sandstone?) (about 19 ft).
Clay shale prograding up to silt shale with possible coal blossom at top (Harlem rider coal?) (about 35 ft).
Sparsely fossiliferous, calcareous clay shale (4½ ft).

Glenshaw Formation

Ames fossiliferous marine siltstone (2 to 3½ ft).
Harlem coal (0.7 to 1.1 ft).
Mottled red and green claystone with limestone nodules (underclay complex) (38+? ft).
Red and green clay shale (Pittsburgh red beds, possibly with Upper Bakerstown coal horizon at base) (30 to 45 ft).
Mixed sequence of sandstone (Saltsburg Sandstone), sand-silt laminite, and silt shale (about 55 ft).
Lower Bakerstown coal horizon (0 to 0.2 ft).
Albright Limestone (0 to 3 ft).
Interbedded sandstone, siltstone, silt shale, and clay shale; occasionally red (Upper Meyersdale red beds) (45 to 50 ft).
Calcareous, black, fossiliferous clay shale (Cambridge-Pine Creek marine zone) (4 to 7 ft).
Unnamed coal (probably the Wilgus coal of Ohio) below Cambridge-Pine Creek marine zone (0 to 1.3 ft).
Rootworked claystone, silt-clay laminite, and nonfossiliferous limestone (underclay complex) (4 to 12 ft).
Clay shale with some siltstone and sandstone (40 to 50 ft).
Carbonaceous clay shale with common marine fossils (4 to 8 ft).
Carbonaceous, calcareous, fossiliferous siltstone and silt shale (Brush Creek marine zone) (0.5 to 3 ft).
Brush Creek coal (0 to 1 ft).
Rootworked claystone and siltstone with occasional hard clay or limestone (underclay complex) (0.2 to 6 ft).
Interbedded sand-silt laminite, silt-clay laminite, siltstone, and clay shale with occasional thin carbonaceous zones and calcareous stringers (20 to 37 ft).

Mahoning coal and/or carbonaceous shale (0 to 2 ft).

Mottled red and green or gray claystone and silty claystone with occasional flinty zones and limestone (0 to 11 ft).

Interbedded sandstone, siltstone, sand-silt laminite, and clay shale with conchostracans—often dominated by thick sandstone (Lower Mahoning sandstone complex) (normally 35 to 60 ft, but ranging up to the order of 100 ft in the proximity of the main Lower Mahoning channel system).

Clay shale, often with abundant conchostracans (0 to 20 ft).

Allegheny Group

Upper Freeport coal.

Because of the lack both of exposures and economic exploitation, no generalizations can be made about lateral stratigraphic variability of units within the Conemaugh Group. It does seem relatively clear that the Lower Mahoning Sandstone has its greatest development in the Punxsutawney-Caledonia syncline, near the southern edge of this report area. With a better biostratigraphic foundation, the marine zones in the Conemaugh would probably be the most convenient and persistent horizons for subdivision of the group.

Measured sections within the Conemaugh Group are included in Appendix 6 (p. A60-A69) and are located at Aa8, Aa6, Ac26, Ac31, Bb15, Bb27, Bc3, Bc5, Bc6, Bc7, Cb2, Cb9, Cb13, Cc1, Cc6, Cc5, Cc14, Db5, Db10, Db11, Eb32, DuBois Fc1, and DuBois Fc2. At Aa3, Ac5, Bb24, and Eb22, the basal Conemaugh is included with measured sections covering the Glen Richey Formation (Appendix 5, p. A54-A59).

Quaternary Alluvium

About six percent of the Sabula-Penfield area has been mapped as Quaternary alluvium. These deposits of gravel, sand, and mud accumulated primarily in the broad, flat valleys—probably during times of increased alluviation during the Pleistocene. The present-day streams are entrenching their courses into the built-up Pleistocene(?) floodplains. Many cut-off meanders in the relict floodplains (especially Sandy Lick Creek) contain considerable organic debris. The texture and constituents of the material mapped as alluvium are treated in more detail under "Sand and Gravel" in the mineral resources section of this report.

GEOLOGIC HISTORY

General

Approximately 16,000 feet of sedimentary rocks overlie the crystalline (Precambrian) basement rocks in this region of the Allegheny Plateau

(Am. Assoc. Petroleum Geologists Basement Rock Project Committee, 1967). Little is known about the Cambrian, Ordovician, and Early and Middle Silurian rocks; the oldest rocks penetrated by one drill hole in the Sabula-Penfield area are Late Silurian in age. It is not known how much increase in the total sedimentary rock thickness has resulted from duplication above décollement surfaces.

The Devonian rocks have been penetrated by many gas wells in the Sabula-Penfield area and the Devonian depositional history is fairly clear. Mississippian and Pennsylvanian strata lend themselves more readily to interpretation because they are exposed at the surface. No post-Pennsylvanian rocks occur in this area other than Quaternary unconsolidated surficial deposits. A long period of erosion and nondeposition has passed since the beginning of the Appalachian orogeny.

Cambrian, Ordovician, and Silurian Periods

The subsurface Cambrian and Early and Middle Ordovician rocks of central and western Pennsylvania have been correlated and analyzed by Wagner (1966) on the basis of widely spaced deep drill holes. These strata in western Pennsylvania (including this report area) indicate deposition of carbonates, quartz sand, and mud in a shallow sea fluctuating across the state.

Toward the end of the Middle Ordovician, this part of Pennsylvania began to feel the effects of the Taconian orogeny, and the Appalachian geosyncline was clearly established as an elongate basin or trough of continental proportions. Clastic sedimentation continued and dark shales were deposited until the end of Ordovician time, when the sea regressed and red beds were deposited in the Queenston delta complex.

During the Silurian Period, the geosyncline in this area continued to subside, but deposits in western Pennsylvania reflect only moderate tectonic activity. In general, clastic sedimentation during the Early Silurian slowly gave way to deposition of carbonates, and finally, during the Late Silurian, to accumulation of evaporites (Salina Group) in a large, restricted basin. The restriction was, in part, due to development of Middle Silurian reefs; the Bloomsburg delta complex formed the eastern and southeastern border of this restricted seaway. Halite, anhydrite, and primary dolomite were precipitated from the highly saline water. The last Silurian deposits were dolomites and limestones of the Bass Islands (Keyser) Group, reflecting a less restricted basin with more normal salinities and open circulation. Further details of Silurian stratigraphy and depositional history are given by Cate (1961, 1965) and by Fergusson and Prather (1968).

Devonian Period

The Silurian-Devonian boundary is in a transition; carbonate (limestone and cherty limestone) deposition continued for a brief span, forming the Helderberg Formation. Deposition of the Ridgeley Sandstone, a horizon of extreme economic importance, followed and was widespread in Pennsylvania. The source area of Ridgeley sand may have been highly weathered and not appreciably uplifted. The good sorting and low clay content of the sand may reflect such a source. This character of the Ridgeley may also be a function of the depositional environment. The widespread occurrence and relatively uniform thickness of the sandstone suggest deposition in a stable, epineritic environment, possibly under the influence of tidal currents. Tidal-current sand ridges are spread over vast areas today (Off, 1963, p. 329) and account for extensive sand accumulation in open seas such as the North Sea. Heyman (1969, p. 6) has offered two alternatives for Ridgeley deposition: (1) draping and concurrent nondeposition of sand on preexisting local seabottom highs; (2) sand deposition grading laterally on a regional scale to finer clastics or nonclastics. These alternatives are offered to explain the "no-sand" area; this large area overlaps the northwestern corner of the Sabula-Penfield area. Deposition of the Ridgeley as tidal-current ridges may partially account for its "disappearance" in the northwestern portion of this report area. At the same time, tidal-current deposition may produce the same effect as nondeposition on seabottom highs.

Following Ridgeley deposition, the Onondaga limestones and cherts accumulated in an open sea supporting normal marine invertebrates. Occasional siltstones and shales reflect pulses of clastic sediment reaching this part of Pennsylvania from a source area to the east.

At the close of the Early Devonian, volcanic activity in the borderlands of the geosyncline spread ash over the sea, resulting in the formation of the Tioga "bentonite." Following that event, the Middle Devonian Hamilton shales filled the sinking basin, reflecting renewed tectonic activity in the source area. This probably marks the beginning of the Acadian orogeny that ultimately gave rise to the formation of the vast Catskill delta complex. Hamilton shales apparently grade northeastward and eastward toward New York and New Jersey into a thick sequence of red beds and continental-fluvial deposits of equivalent age.

In this report area, the dark Hamilton shales are overlain by the Tully Formation, a sequence of marine limestones. The development of the Tully limestones reflects a pause in the orogeny when large amounts of detrital material were not reaching this portion of the geosyncline.

During the Late Devonian, Acadian orogenic activity was expressed in this area by deposition of a thick clastic sequence of marine shales and sandstones followed by deposition of continental red beds. This whole sequence is part of the great Catskill delta complex. The volume of sediment being poured into this part of the shallow sea increased and slowly moved the shoreline to the west. Minor fluctuations and reversals in this trend produced a thick complex of differing facies with limited areal extent. Many thin sand bodies accumulated as the shoreline regressed and transgressed. Fossiliferous shelf or prodelta muds interfinger upward into offshore sand bars and delta-front muds and sands. Beach sands grade laterally into tidal-flat silts and clays. The net shoreline movement throughout the Late Devonian is one of regression, but many minor reversals are recorded in the rock sequence.

The last Devonian event in this area was deposition of a thick sequence of red beds. More regional studies support the fact that this red-bed lithosome thickens to the east. The authors hold the traditional view that the red-bed sequence of the Late Devonian is a dominantly subaerial deposit, but very close to sea level and associated with delta-plain deposition. Many of the red claystones may be tidal-mudflat deposits.

The time boundary between the Devonian Period and the succeeding Mississippian Period is arbitrarily placed at the top of the thick red-bed sequence. The end of Devonian time may well be represented in part of the overlying nonred clastic section, but that possibility has not been documented. Deposition clearly continued uninterrupted into Mississippian time in the Sabula-Penfield area.

Mississippian Period

The lower part of the Pocono Formation reflects a return to shallow marine and deltaic deposition, much like the Late Devonian prior to red-bed formation. Marine fossils are profuse in the sands. Occasional red and green claystones may well be the remains of tidal mudflats. Plant fossils are also abundant, but no coal swamps like those of the Pennsylvanian formed in the Early Mississippian in this report area.

The middle "Patton" red-bed section of the Pocono probably represents a return to tidal flat-lower delta plain deposition which characterized the end of the Late Devonian. The "Patton" is not entirely red, and is the result of frequently alternating marine and nonmarine deposition. Delicate plant fossils are common (especially in the nonred sediments), indicating nearshore, shallow conditions.

The upper part of the Pocono, the Burgoon Sandstone, reflects a change to dominantly fluvial deposition on a broad alluvial plain. Trough cross stratification, absence of marine invertebrates, presence of large plant fossils, predominance of quartzose sandstone, and paucity of shale point to a fluvial origin for the Burgoon.

Deposition of this upper member of the Pocono was the last Mississippian depositional event left in the stratigraphic record in the Sabula-Penfield area. Pelletier (1958) presents a fine summary of Pocono sedimentary history.

Following Pocono deposition, a period of possible nondeposition and regional erosion produced the Mississippian-Pennsylvanian unconformity. The Mauch Chunk Formation and Loyalhanna Limestone of south-central and southwestern Pennsylvania are missing in the Sabula-Penfield area and appear to have been lost progressively in a northerly direction. The unconformity is demonstrated not only by lack of post-Pocono formations, but also by apparent beveling of the Pocono itself across the Penfield 15-minute quadrangle. Paleobotanical evidence (Edmunds and Berg, 1971) strongly supports the interpretation of an unconformity. At the northern edge of this report area, the Burgoon and "Patton" members are missing. That this loss of Pocono subunits may be due to nondeposition or facies change should not be entirely discounted. By the very nature of Pocono sedimentation as outlined by Pelletier (1958), we should expect some regional thinning and loss of fluvial and nearshore deposits in a northwesterly direction across Pennsylvania.

Pennsylvanian Period

Pennsylvanian time in the Sabula-Penfield area is marked by deposition of the Pottsville Group. If present paleobotanical zonation and stratigraphic correlations in the Appalachian Basin are correct, there are no rocks representing the first 40 percent of the Pennsylvanian Period in this area. The period of erosion of Mississippian rocks extended far into Pennsylvanian time.

The quartzitic conglomerates and very coarse grained sandstones of the lower part of the Pottsville reflect a significant departure from the depositional environments of the Mississippian. The rounded quartzite pebbles and general lack of other less resistant clasts indicate a distant source area. The fluvial system carrying these sediments must have been very competent and heavily loaded. Plane bedding, in addition to tabular crossbedding, frequently occurs in the Pottsville sandstones and probably reflects a high lower flow regime to an upper flow regime for the streams. Meckel (1967) has given substantial regional evidence that the basal Pottsville (Olean-Sharon) conglomerates were derived from a source to the north and were spread over an irregular erosion surface. The lack of coarse conglomerates in the Pottsville in the southern part of this report area indicates that the southern limit of Olean deposition passes through this area. These fluvial sands and gravels were spread across the eroded Mississippian surface. The Burgoon Sandstone is believed to have formed a long, low ridge, lying east-west across the central part of Clearfield County. This theoretical paleotopography was the result of pre-Pottsville erosion. This ridge may have formed a barrier that acted as one of the limiting agents for spread of pebble-sized material in the Pottsville.

Following the deposition of the lower part of the Pottsville Group, Pennsylvanian deposition is characterized by strongly cyclic sedimentation and the introduction of coal as a persistent lithologic entity in the sequence. The basic Pennsylvanian sedimentary cycle of transgression and regression that we recognize has been treated in detail by Edmunds (1968) and Edmunds and Berg (1971). A sequence of six depositional environments are recognized in one cycle. These are listed in order of depositional sequence starting with the transgressive coal swamp as follows:

1. Transgressive swamp environment
2. Open-water (shelf, prodelta, interdeltaic bay) and brackish mudflat environment
3. Regressive swamp environment
4. Delta-plain environment
5. Alluvial-plain environment (with concomitant erosion)
6. Backswamp and freshwater lake environment

The sediments formed in these environments are theoretically unique (because the environments of deposition are unique relative to one another), but in practice they are sometimes difficult to differentiate. For example, the sediments of the delta plain and alluvial plain interfinger upward in many sequences. Lacking a clear disconformity, it is hard to distinguish some delta-plain sands from fine, alluvial-plain sands. Missing units also complicate identification of cycle components.

The Millstone Run Formation in the Allegheny Group is the best exposed cycle in the Sabula-Penfield area and displays a fair representation of the Pennsylvanian sedimentary cycle. The main transgressive swamp environment is reflected partly in the Lower Kittanning no. 1 coal, but mostly in the Lower Kittanning no. 3 coal. It may be possible that the Lower Kittanning no. 3 coal is a retrograde coal in the Sabula-Penfield area as it has been interpreted in the Houtzdale area (Edmunds, 1968). However, the absence of the Lower Kittanning no. 2 coal, the extremely poor development of the Lower Kittanning no. 1 coal, and the lack of open-water sediments below the Lower Kittanning no. 3 coal lead the writers to believe that what has been called Lower Kittanning no. 3 is indeed the result of accumulation of peat in the major transgressive swamp. The backswamp complex preceding the transgressive swamp left a thick underclay section and has associated hard clay lenses. Backswamp conditions prevailed in this area while Lower Kittanning no. 1 and no. 2 coals were formed elsewhere in the basin. Following deposition of the

Lower Kittanning no. 3 coal, the transgressive open-water shales and laminites were deposited with a rich marine invertebrate fauna. In the southern Penfield area (Edmunds and Berg, 1971) this part of the cycle does not bear such a clearly marine fauna, but displays mainly restricted-marine invertebrates, particularly *Lingula*. This change in the open-water environment in a southerly and southeasterly direction across the Penfield 15-minute quadrangle clearly indicates increasing nearness to the edge of the depositional basin and possible reduction in salinity. The upper part of the open-water component in this area is a widespread siltstone bearing marine brachiopods. This is interpreted as a delta-front distal bar or prodelta silt body formed at the time of cycle reversal from transgression to regression. Sands below this horizon are also believed to have been deposited in open water as offshore bars or as bay fillings, representing minor fluctuations in the general transgression. A black shale over the marine siltstone may be the horizon of the regressive swamp environment, but no coal was ever deposited at this stage in the Sabula-Penfield area. The Lower Worthington sandstone probably represents fluvial deposition in an alluvial-plain environment at a point in time marking maximum sea regression. This sand lithosome is not everywhere present, nor is it clearly recognizable as an alluvial deposit. It is probably expressed as upper delta plain distributary sands and laterally equivalent levee and crevasse-splay (break-in-levee) deposits. The Lower Worthington sandstone is much better developed in the southern Penfield area, again reflecting nearness to the edge of the basin. The last event of the Millstone Run cycle was accumulation of clay in a backswamp environment prior to transgression of the Middle Kittanning coal swamp.

The Allegheny Group displays a decreasingly marine character, going up through the total sequence of cycles. The first cycle, the Clearfield Creek Formation, includes the fossiliferous marine Vanport Limestone. Open-water shales of the overlying Millstone Run Formation bear a clearly marine fauna. Some brackish and marine fossils are found in the open-water shales of the succeeding Mineral Springs Formation. The upper two cycles (Laurel Run and Glen Richey Formations) bear no marine fossils and actually yield fair numbers of conchostracans, which are freshwater arthropods. Hence, the depositional basin during formation of the Allegheny Group in this area was progressively cut off from the main epicontinental sea to the west.

The Allegheny Group is well known for the presence of minable coal seams. The absence of certain lithologies also makes it unique. No red beds have been found anywhere in the Allegheny in the Sabula-Penfield area. In addition, no sand body has definitely been identified as a beach deposit. This lack of red clays and obvious beach sands may be attributed to the general paucity of wide expanses of open-marine water during Allegheny deposition. There apparently was little fetch and not enough wave energy to build up beaches in this area, although some offshore bars have been inferred. At the same time, there was not enough open circulation in the basin to allow oxidation of the sediments and formation of red clays.

The lower part of the Conemaugh Group (Glenshaw Formation) differs from the Allegheny in having only poorly developed coals; red beds occur along with marine zones bearing quite varied invertebrate faunas. These characteristics reflect much more open marine conditions and no extensive barrier-bar sands. Red beds formed as open-water clays were oxidized. Not enough is known about the upper part of the Conemaugh to interpret depositional environments. It is fairly clear, however, that open-marine conditions were not repeated after deposition of the Ames marine siltstone.

During the Pennsylvanian, uplift of the source area was gradual, persistent, and possibly cyclic. Sometime during deposition of the Pottsville Group, the source of sediment switched from the north back to the southeast as it was during the Mississippian. The paleoslope during the post-Pottsville Pennsylvanian was dipping generally to the west and northwest.

Post-Pennsylvanian Time

Near the end of the Paleozoic Era (approximately 225 million years ago), deposition in the Appalachian geosyncline had ceased and a period of uplift and erosion called the Alleghenian orogeny began. With the onset of this orogeny, the Paleozoic rocks in the geosyncline were uplifted, folded, and faulted. The broad folds and subsurface reverse faults in this report area all date from this period of tectonism. The uplifted sedimentary rocks have been subjected to continual erosion ever since.

Quaternary Period

The broad valley bottoms in the Sabula-Penfield area contain alluvial deposits with entrenched streams. Deposition of alluvium was probably much more rapid during the Pleistocene Epoch when climatic extremes accompanying glacial advance and retreat were greater. Periglacial conditions also increased physical weathering by frost heaving.

STRUCTURAL GEOLOGY

INTRODUCTION

An understanding of the structure, or three-dimensional configuration, of bedrock is important to interpretation of all the other geologic aspects of the Sabula-Penfield area. The extent of mineral resources, flow of ground water, and rock stability for construction are partly determined by structure.

This part of the Allegheny Plateau is dominated by the Punxsutawney-Caledonia syncline; its axis crosses the map area in a northeast direction. The syncline is flanked on the southeast by the broad Chestnut Ridge anticline, described in detail by Edmunds and Berg (1971, p. 67) in the southern Penfield area. The syncline is flanked on the northwest by the Boone Mountain (Sabinsville) anticline. A major fault has been mapped at the surface (the Mountain Run fault), and extensive faulting in the subsurface has been mapped by Cate (1961), based on a study of deep gas well drilling. The cross section on Plate 1 shows the structure as it appears roughly at right angles to the fold axes.

STRUCTURAL DATUM PLANES

Three stratigraphic datum planes are used here in determining the structure in the Sabula-Penfield area. The most reliable datum is the Lower Kittanning no. 3 coal in the Allegheny Group. Where this is not present, the base of the Curwensville Formation and the top of the major red-bed sequence (Catskill) in the Upper Devonian are used.

The base of the Curwensville Formation is used in the southeastern portion of this report area. The base of the Curwensville is a good datum where the Mercer hard clay is present. Because the Sabula-Penfield area lies beyond the northernmost immediate extent of the Mercer hard clay, the base of the Curwensville Formation is estimated by projection down from the base of the Homewood Sandstone Member of the Curwensville. Photogeologic methods are used almost exclusively to locate the base of this sandstone. In addition, the exposures along Interstate Route 80 just to the south of this report area aided the authors' understanding of the stratigraphy of the Curwensville and Elliott Park Formations (Pottsville Group).

The top of the major red-bed sequence in the Upper Devonian section is used on the Boone Mountain anticline; the only other possible datum may be the base of the Pottsville Group, which is believed to be an unconformity with an irregular surface. As discussed in the section on "Subsurface Stratigraphy" in this report, this is probably the only reliable datum for the Boone Mountain area. There really is no other choice of good datum planes, and extensive drilling records for shallow gas on the anticline provide fairly reliable information. The extent of the red-bed sequence is shown in Plates 2, 3, and 4. In the area just south of the Jefferson County line (quadrant Ab) and in the vicinity of the two Brockway Borough reservoirs (quadrant Ba), virtually no datum of any reliability is available; no extensive outcrops exist and no drilling has been done to provide elevations on the Devonian red beds. Structure contours in these areas are projected by inference and are questionable.

The Lower Kittanning no. 3 coal is used as a datum in the central part of the report area using elevations based on deep mines and strip mine exposures. Where no information was available, the elevations of this coal were estimated by projection down from known stratigraphically higher horizons in the Allegheny and Conemaugh Groups. Intervals used in such projections were based on long drilling records (Plate 5).

FOLDS

The Boone Mountain anticline has an axial bearing of about N55E; its axis is shown on Plate 1. The fold plunges gently to the southwest, and has an asymmetric profile with its southeastern flank more steeply dipping than the northwestern flank. Along the southeastern flank, the strata are interpreted as dipping up to 600 feet per mile. On the northwestern flank, the steepest dips are on the order of 300 feet per mile, at the most.

The Punxsutawney-Caledonia syncline, with an axial bearing of about N50E, has a generally straight trend, except for a minor divergence near Sabula. The syncline is doubly plunging from both the southwest and the northeast toward the vicinity of Lake Sabula, forming a very elongate structural basin.

On the northwestern flank of the Chestnut Ridge anticline, the dips average about 250 feet per mile. Although the axis of this fold passes south of this report area, it is the dominant structure in the southern Penfield area.

The fold height (structural relief), measured from the bottom of the Punxsutawney-Caledonia syncline to the top of the Boone Mountain anticline (along line A-A′, Plate 1), is on the order of 1750 feet. This includes about 400 feet of vertical displacement by the Mountain Run fault. The wavelength of the Punxsutawney-Caledonia syncline is about 12½ miles, measured between the axes of the two flanking anticlines.

FAULTS

Cate (1961) has plotted many high-angle faults in the subsurface of this area (Figure 16) on the basis of a detailed study of deep gas well records. These faults are probably related to movements along deep

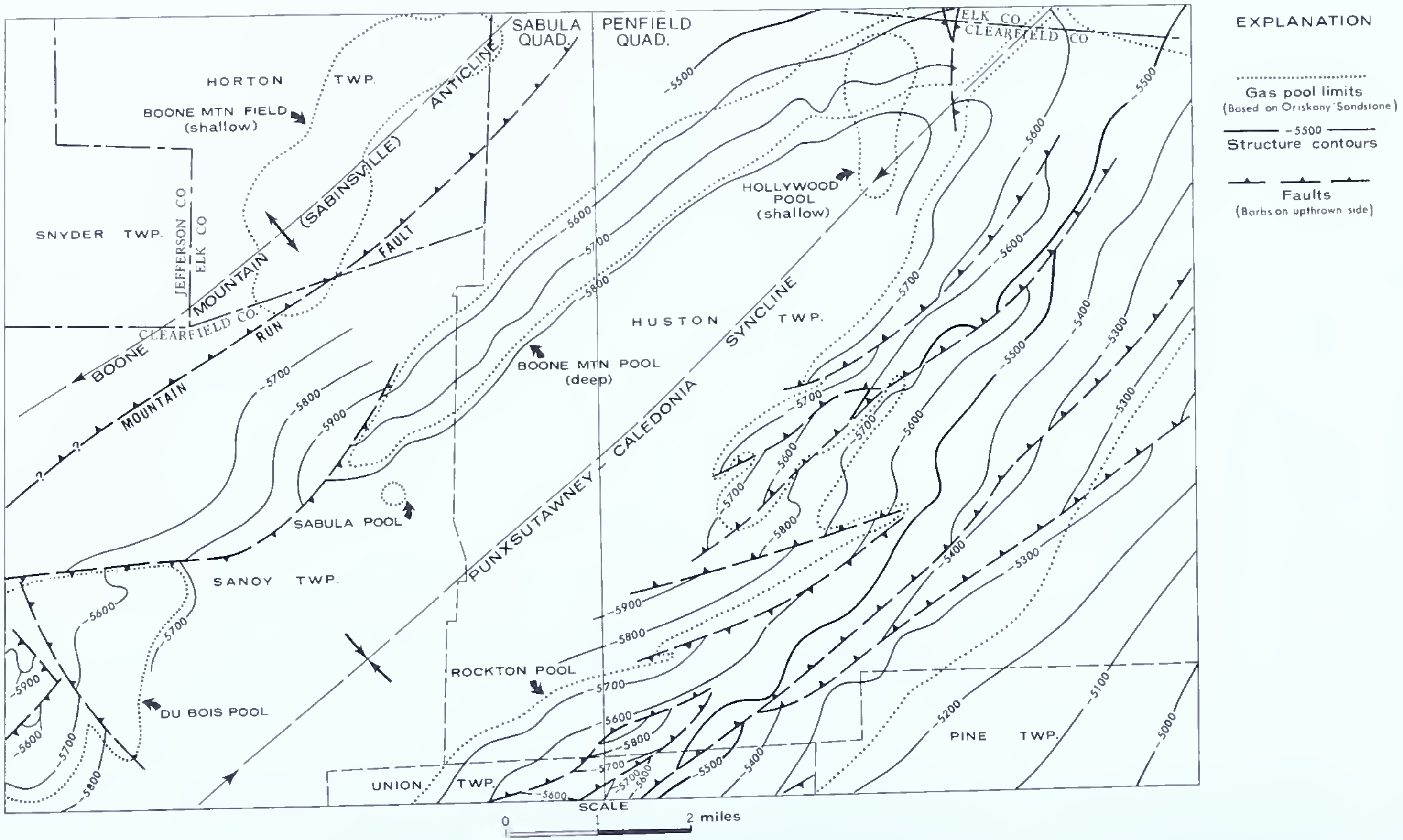

Figure 16. Subsurface structural geology, based on the "Oriskany" (Ridgeley) Sandstone, and limits of gas fields and pools (adapted from Cate, 1961).

décollement slip surfaces. The genesis of this kind of faulting is treated in more detail by Edmunds and Berg (1971) for the southern Penfield area.

Of particular interest and importance is the existence of a major surface fault that has topographic expression along Mountain Run on the southeastern flank of the Boone Mountain anticline. This fault is anomalous for the Allegheny Plateau; we know of only two similar faults. One was mapped by Shaffner (1958, p. 76) in the New Florence 15-minute quadrangle. Another was described by Ashburner (1880, p. 34) in the southeastern corner of McKean County.

The Mountain Run fault is unusual in that the fault surface is apparently nonplanar. If it were planar, the fault trace would indicate a very low angle (8°±) fault. Nonrepetition of stratigraphic units in the subsurface negates low-angle faulting. The upthrown block lies on the northwestern side of the fault with a maximum displacement estimated at about 400 feet. This fault is illustrated in Plate 2, where the upper Devonian red beds are shown to be offset by more vertical displacement than can be accounted for by folding. Cate (1961) also inferred a fault in this vicinity based on his subsurface study of the Oriskany Group (Figure 16).

Although relative movement is known, the Mountain Run fault is difficult to classify. If the fault surface dips toward the Punxsutawney-Caledonia syncline, the fault must be a normal fault. If the surface dips toward the northwest, the fault must be a reverse fault. Normal faulting does not appear to fit the tectonic style for this region as described by Edmunds and Berg (1971). Faulting in the subsurface of this region has been described by Gwinn (1964, p. 891) as being related to concentric folding and flexural-slip thrusting. In light of Gwinn's theoretical work, the authors do not favor the possibility of normal faulting, and prefer to classify this as a steeply dipping, if not vertical, reverse fault at the surface, with the fault plane slowly curving down beneath the Boone Mountain anticline. This fault is probably similar to the model shown by Carlyle Gray for faulting in the New Florence quadrangle (Shaffner, 1958, p. 76).

JOINTS

Joints in this region generally have a near vertical orientation. Bearings of joints at 49 stations were taken, and the results are shown in the rose diagram in Figure 17. The joints are also plotted on Plate 1. Our interpretation of the rose diagram is that there are two dominant joint

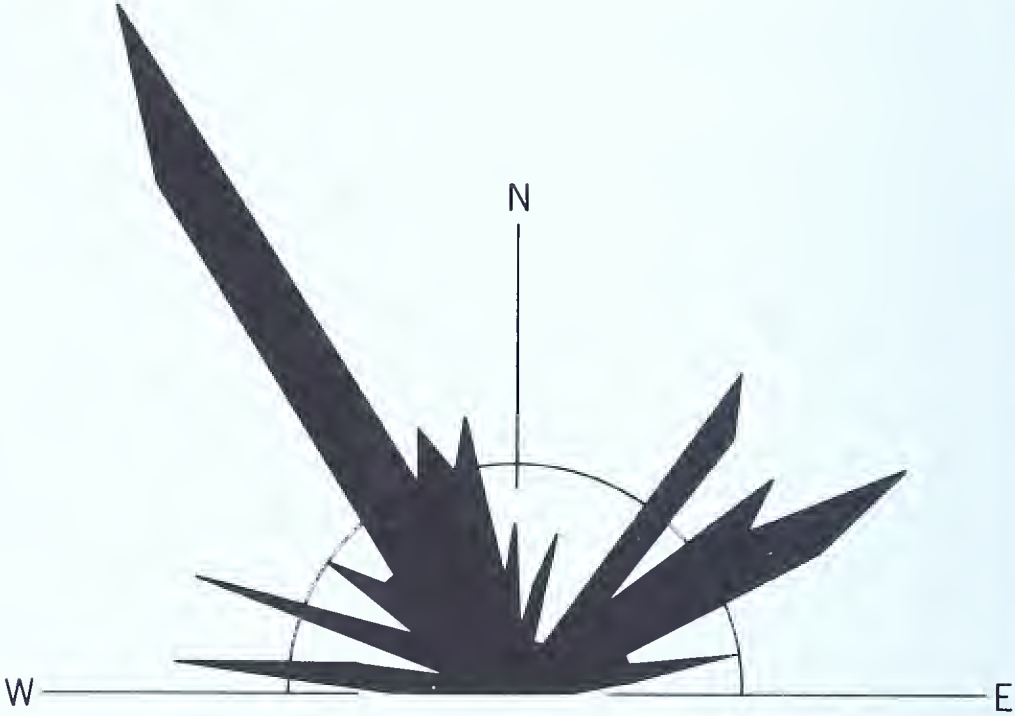

Figure 17. Rose diagram showing joint bearings in the Sabula and Penfield quadrangles. Radius of semicircle equals 4 joint readings.

systems in the Sabula-Penfield area. The principal system includes the most prevalent set, bearing about N30W with a strong complemental set bearing N60E; the complemental set has a significant deviation towards N50E. This system contains one set parallel to, and one set normal to, major fold axes. It can, therefore, be considered to be related to late folding stresses. A system of secondary importance has sets which are roughly complementary, but its existence is difficult to determine without a more detailed study. There appears to be a set ranging from N70W to N85W with an apparent approximate complemental set bearing N35E. Other less significant joint bearings were measured.

The joints were measured in various rock units, ranging from sandstone and siltstone to shales and claystone. No face or butt joints in coals were measured for this analysis. Although no exhaustive study was undertaken, it has been the authors' observation that joint planes are generally more closely spaced in the finer clastic rocks than in the coarser clastics. In clay shales and claystones, spacing usually varies from a few inches to 2 feet. In siltstones and laminites, the spacing varies from about 6 inches to 6 feet. The joint spacing in sandstones is on the order of 2 to 10 feet.

MINERAL RESOURCES

COAL

General

Coal beds in the Sabula-Penfield area occur throughout the Pennsylvanian rocks, which measure more than 1000 feet in thickness in the deeper portions of the Punxsutawney-Caledonia syncline. Minable coals are confined to the Allegheny Group within a stratigraphic interval of about 200 feet (Plate 1). Although data are limited, it appears that most of these coals are sporadic in nature and that only one coal, the Lower Kittanning no. 3 seam, has widespread development. It underlies all of the report area except for the southeastern portion and the area along Boone Mountain.

Most of the mining activity being conducted in the area during the course of this study was centered around Penfield, where some small stripping operations and a few deep mines were operating. The coal was being used as steam coal for electric power generation.

Chemical and Physical Characteristics

Previously published as well as unpublished coal analyses from the Sabula-Penfield area are shown in Tables 1, 2, and 3. On a "moisture and ash-free" basis, most of these coals have less than 69 percent fixed carbon and are classified as "high-volatile-A bituminous coal." The only exceptions are the upper bench of the Middle Kittanning seam, sample no. 410949/783247/1B, which shows 69.2 percent fixed carbon, and the top bench of the lower Mercer coal, sample no. 411211/783847/1E, with 72.6 percent fixed carbon. Both of these benches would be classed as "medium-volatile bituminous coals."

A study of the carbonizing properties of Elk, Clarion, Jefferson, Clearfield, and Centre County coals is given in Birge and others (1963). One of the coal samples used in that report (sample no. 833) was taken from a mine in the Sabula-Penfield area.

The following conclusions concerning the coals in this area were made in that report:

1. The coke strength indexes of all samples were within the normal range for coking purposes.
2. The high-volatile coals contracted during oven expansion tests, indicating that these coals would have to be blended to prevent oven damage.
3. Metallurgical use of most of the samples would be limited because of high sulfur and/or ash content.

Table 1. *Analyses of Coal Samples from the Sabula and Penfield Quadrangles*

Reference number	Coal bed	Source of information	Coal sample number	Thickness (feet)	Sample condition[1]	Proximate analysis				Ultimate analysis						BTU[2]	Fusibility of ash, °F			FSI
						Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Ash		Initial deformation temperature	Softening temperature	Fluid temperature	
Ec3	LK3	Wise Run strip mine	410951/783240/1B	1.1	AR	1.1	29.2	60.4	9.3	2.6	4.9	78.0	1.3	3.9	9.3	13,760	2090	2140	2260	—
					Dry		29.5	61.1	9.4	2.6	4.8	78.8	1.3	3.1	9.4	13,900				
					MAF		32.6	67.4		2.9	5.3	87.0	1.5	3.3		15,350				
			Bone	0.1	Not analyzed															
			410951/783240/1A	1.6	AR	1.1	30.6	61.7	6.6	3.0	5.1	79.6	1.4	4.3	6.6	14,150	2130	2180	2250	9
					Dry		31.0	62.3	6.7	3.0	5.0	80.5	1.4	3.4	6.7	14,300				
					MAF		33.2	66.8		3.2	5.4	86.3	1.5	3.6		15,330				
			Composite of −/1B, −/1A	2.7 (2.8)	AR	1.1	30.0	61.2	7.7	2.8						14,000				
					Dry		30.4	61.8	7.8	2.9						14,100				
					MAF		32.9	67.1		3.1						15,300				
Ec2	MK	Wise Run strip mine	410949/783247/1B	1.3	AR	1.9	29.2	65.8	3.1	0.7	5.1	82.0	1.5	7.6	3.1	14,330	2910+	—	—	—
					Dry		29.8	67.0	3.2	0.7	5.0	83.6	1.6	5.9	3.2	14,600				
					MAF		30.8	69.2		0.7	5.1	86.3	1.6	6.3		15,080				
			Black shale parting	0.1	Not analyzed															
			410949/783247/1A	0.6	AR	1.9	29.1	63.3	5.7	1.1	4.8	78.2	1.5	8.7	5.7	13,740	2910+	—	—	3½
					Dry		29.6	64.6	5.8	1.1	4.7	79.7	1.5	7.2	5.8	14,000				
					MAF		31.5	68.5		1.2	4.9	84.6	1.6	7.7		14,860				
			Composite of −/1B, −/1A	1.9 (2.0)	AR	1.9	29.2	65.0	3.9	0.8						14,100				
					Dry		29.7	66.3	4.0	0.8						14,400				
					MAF		31.0	69.0		0.9						15,000				

Eb39	LK3	Face of Bark Camp #1 mine	411042/783413/1B	0.9	AR	0.7	30.5	63.3	5.5	1.8	5.1	82.4	1.4	3.8	5.5	14,500	2080	2130	2180	8½
					Dry		30.7	63.7	5.6	1.8	5.0	83.0	1.4	3.2	5.6	14,610				
					MAF		32.5	67.5		1.9	5.3	87.9	1.5	3.4		15,470				
			Bone	0.1	Not analyzed															
			411042/783413/1A	1.6	AR	0.8	30.8	61.1	7.3	3.5	5.0	79.5	1.4	3.3	7.3	14,160	2130	2180	2290	—
					Dry		31.0	61.6	7.4	3.6	5.0	80.1	1.4	2.5	7.4	14,270				
					MAF		33.5	66.5		3.9	5.4	86.5	1.5	2.7		15,410				
			Composite of −/1B, −/1A	2.5 (2.6)	AR	0.8	30.7	61.9	6.7	2.9						14,300				
					Dry		30.9	62.4	6.7	2.9						14,400				
					MAF		33.1	66.8		3.1						15,400				
Near Eb39	LK3	200 ft in main heading at Bark Camp #1 mine	411043/783413/1B	0.9	AR	0.7	30.3	63.2	5.8	2.3	5.1	82.4	1.4	3.0	5.8	14,540	2130	2180	2240	8½
					Dry		30.5	63.7	5.8	2.3	5.0	82.9	1.4	2.6	5.8	14,640				
					MAF		32.4	67.6		2.4	5.3	88.1	1.5	2.7		15,540				
			Bone	0.1	Not analyzed															
			411043/783413/1A	1.4	AR	0.8	29.4	64.6	5.2	2.3	5.2	82.0	1.4	3.9	5.2	14,580	2130	2180	2410	8½
					Dry		29.7	65.1	5.2	2.3	5.2	82.7	1.4	3.2	5.2	14,700				
					MAF		31.3	68.7		2.4	5.5	87.2	1.5	3.4		15,510				
			Composite of −/1B, −/1A	2.3 (2.4)	AR	0.8	29.8	64.1	5.4	2.3						14,600				
					Dry		30.0	64.5	5.5	2.3						14,700				
					MAF		31.7	68.3		2.5						15,500				
Dc19	Clarion	Roadcut on I 80, sta. 612+50 W.B., section 25-26	410738/783503/1B	0.5	AR	0.9	22.5	40.0	36.6	0.8	3.3	52.7	0.8	5.8	36.6	9,140	2910+	—	—	—
					Dry		22.7	40.3	37.0	0.8	3.2	53.2	0.8	5.0	37.0	9,220				
					MAF		35.9	64.1		1.3	5.1	84.4	1.3	7.9		14,630				
			Shale parting	0.2	Not analyzed															
			410738/783503/1A	0.45	AR	0.6	29.8	46.6	23.0	3.5	4.1	63.7	1.1	4.6	23.0	11,460	2580	2630	2680	7½
					Dry		30.0	46.9	23.1	3.6	4.0	64.1	1.1	4.1	23.1	11,530				
					MAF		39.0	61.0		4.6	5.2	83.4	1.4	5.4		15,000				
			Composite of −/1B, −/1A	0.95 (1.15)	AR	0.8	26.0	43.1	30.2	2.1						10,200				
					Dry		26.2	43.5	30.4	2.1						10,300				
					MAF		37.6	62.4		3.0						14,800				

Table 1. (*Continued*)

Reference number	Coal bed	Source of information	Coal sample number	Thickness (feet)	Sample condition¹	Proximate analysis				Ultimate analysis						BTU²	Fusibility of ash, °F			FSI
						Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Ash		Initial deformation temperature	Softening temperature	Fluid temperature	
Cb3	E	Sabula drill core	411211/783847/1C	0.25	AR	0.7	25.5	41.8	32.0	3.7	3.8	56.8	1.0	2.7	32.0	10,070	2190	2260	2520	4½
					Dry		25.6	42.2	32.2	3.7	3.7	57.2	1.0	2.2	32.2	10,130				
					MAF		37.8	62.2		5.5	5.5	84.4	1.5	3.1		14,950				
			411211/783847/1B	1.4	AR	1.6	31.6	58.2	8.6	2.4	5.1	77.6	1.5	4.8	8.6	13,780	2080	2180	2390	9
					Dry		32.1	59.2	8.7	2.4	5.0	78.8	1.5	3.6	8.7	14,000				
					MAF		35.1	64.9		2.7	5.5	86.3	1.7	3.8		15,340				
			411211/783847/1A	0.5	AR	1.3	26.0	47.8	24.9	1.4	4.2	62.8	1.2	5.5	24.9	11,150	2680	2730	2780	7½
					Dry		26.4	48.3	25.3	1.5	4.1	63.7	1.3	4.1	25.3	11,300				
					MAF		35.3	64.7		2.0	5.5	85.2	1.7	5.6		15,110				
			Composite of −/1C, −/1B, −/1A	2.15	AR	1.4	29.6	53.9	15.1	2.3						12,700				
					Dry		30.0	54.7	15.3	2.4						12,900				
					MAF		35.4	64.5		2.8						15,300				
Cb3	D	Sabula drill core	411211/783847	2.3	AR	1.2	32.2	60.8	5.8	1.1	5.1	80.7	1.6	5.7	5.8	14,330	2250	2360	2580	9
					Dry		32.6	61.5	5.9	1.2	5.0	81.7	1.7	4.5	5.9	14,510				
					MAF		34.7	65.3		1.2	5.3	86.8	1.8	4.9		15,410				
Cb3	C′	Sabula drill core	411211/783847/1C	0.2	AR	0.6	25.8	50.4	23.2	2.9	4.1	65.0	1.1	3.7	23.2	11,520	2410	2460	2520	4½
					Dry		26.0	50.7	23.3	2.9	4.0	65.4	1.1	3.3	23.3	11,590				
					MAF		33.8	66.2		3.8	5.2	85.3	1.4	4.3		15,120				
			411211/783847/1B	1.0	AR	1.1	32.1	56.8	10.0	3.1	5.0	75.7	1.5	4.7	10.0	13,490	2030	2080	2150	9
					Dry		32.4	57.5	10.1	3.2	4.9	76.5	1.5	3.8	10.1	13,640				
					MAF		36.1	63.9		3.5	5.4	85.1	1.6	4.4		15,170				
			411211/783847/1A	0.67	AR	0.9	29.1	52.6	17.4	2.0	4.6	69.8	1.4	4.8	17.4	12,440	2660	2710	2760	7
					Dry		29.4	53.1	17.5	2.0	4.5	70.5	1.4	4.1	17.5	12,550				
					MAF		35.6	64.4		2.4	5.4	85.5	1.7	5.0		15,220				

			Composite of −/1C, −/1B, −/1A	1.87	AR	1.0	30.3	54.6	14.1	2.7						12,900				
					Dry		30.6	55.1	14.2	2.7						13,000				
					MAF		35.7	64.3		3.2						15,200				
Cb3	MK rider	Sabula drill core	411211/783847	0.75	AR	0.8	25.5	42.3	31.4	2.5	3.9	56.4	1.0	4.8	31.4	10,100	2520	2570	2620	5½
					Dry		25.7	42.6	31.7	2.5	3.8	56.9	1.0	4.1	31.7	10,200				
					MAF		37.6	62.4		3.6	5.6	83.3	1.5	6.0		14,900				
			411211/783847/1C	0.6	AR	0.8	30.8	59.2	9.2	0.7	5.1	78.6	1.4	5.0	9.2	13,920	2910+	—	—	6½
					Dry		31.1	59.6	9.3	0.7	5.0	79.2	1.4	4.4	9.3	14,030				
					MAF		34.2	65.8		0.8	5.5	87.4	1.6	4.7		15,470				
			411211/783847/1B	0.52	AR	1.0	31.9	59.9	7.2	0.8	5.1	79.9	1.5	5.5	7.2	14,130	2910+	—	—	8½
					Dry		32.2	60.5	7.3	0.8	5.0	80.7	1.5	4.7	7.3	14,260				
					MAF		34.7	65.3		0.9	5.4	87.0	1.6	5.1		15,380				
Cb3	MK	Sabula drill core	Black claystone parting	.18	Not analyzed															
			411211/783847/1A	0.2	AR	1.2	28.1	51.3	19.4	5.5	4.3	66.1	1.2	3.5	19.4	11,840	2130	2180	2270	5½
					Dry		28.4	52.0	19.6	5.5	4.2	66.9	1.2	2.6	19.6	11,980				
					MAF		35.3	64.7		6.9	5.2	83.2	1.5	3.2		14,910				
			Composite of −/1C, −/1B, −/1A	1.32 (1.50)	AR	0.9	30.8	58.3	10.0	1.5						13,700				
					Dry		31.1	58.8	10.1	1.5						13,800				
					MAF		34.6	65.4		1.6						15,400				
Cb3	LK3	Sabula drill core	411211/783847/1C	0.95	AR	0.9	32.1	60.8	6.2	3.3	5.2	79.4	1.4	4.5	6.2	14,210	2050	2100	2160	8½
					Dry		32.4	61.4	6.2	3.4	5.1	80.1	1.4	3.8	6.2	14,340				
					MAF		34.5	65.5		3.6	5.5	85.5	1.5	3.9		15,290				
			Bone	0.05	Not analyzed															
			411211/783847/1B	1.3	AR	1.2	31.7	61.8	5.3	2.1	5.2	80.6	1.4	5.4	5.3	14,430	2060	2160	2260	9
					Dry		32.1	62.5	5.4	2.1	5.1	81.6	1.5	4.3	5.4	14,610				
					MAF		33.9	66.1		2.2	5.4	86.3	1.5	4.6		15,440				
			411211/783847/1A	0.8	AR	1.1	30.2	57.5	11.2	4.3	4.9	74.2	1.2	4.2	11.2	13,270	2040	2140	2260	9
					Dry		30.6	58.1	11.3	4.4	4.8	75.0	1.2	3.3	11.3	13,420				
					MAF		34.5	65.5		4.9	5.4	84.6	1.4	3.7		15,130				
			Composite of −/1C, −/1B, −/1A	3.05 (3.10)	AR	1.1	31.4	60.4	7.1	3.1						14,100				
					Dry		31.8	61.0	7.2	3.1						14,200				
					MAF		34.2	65.8		3.3						15,300				

Table 1. (*Continued*)

Reference number	Coal bed	Source of information	Coal sample number	Thickness (feet)	Sample condition[1]	Proximate analysis				Ultimate analysis						BTU[2]	Fusibility of ash, °F			FSI
						Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Ash		Initial deformation temperature	Softening temperature	Fluid temperature	
Cb3	UM2	Sabula drill core	411211/783847	1.2	AR	0.7	31.0	59.6	8.7	4.0	4.9	77.8	1.2	3.4	8.7	13,890	2030	2080	2140	7½
					Dry		31.2	60.0	8.8	4.0	4.8	78.4	1.2	2.8	8.8	13,990				
					MAF		34.2	65.8		4.4	5.3	86.0	1.4	2.9		15,330				
Cb3	UM1	Sabula drill core	411211/783847	0.6	AR	0.7	25.2	53.2	20.9	1.0	4.2	67.6	0.9	5.4	20.9	11,860	2910+	—	—	6½
					Dry		25.4	53.5	21.1	1.0	4.2	68.1	0.9	4.7	21.1	11,940				
					MAF		32.2	67.8		1.2	5.3	86.3	1.2	6.0		15,130				
			411211/783847/1E	0.85	AR	0.4	20.0	53.1	26.5	3.1	3.4	62.5	0.9	3.6	26.5	10,770	2570	2620	2680	2½
					Dry		20.1	53.3	26.6	3.1	3.4	62.7	0.9	3.3	26.6	10,810				
					MAF		27.4	72.6		4.2	4.6	85.4	1.2	4.6		14,730				
			411211/783847/1D	0.25	AR	0.5	24.7	49.2	25.6	1.0	4.0	63.5	1.0	4.9	25.6	11,090	2910+	—	—	3
					Dry		24.8	49.4	25.8	1.0	3.9	63.8	1.0	4.5	25.8	11,140				
					MAF		33.4	66.6		1.4	5.3	86.0	1.3	6.0		15,010				

Cb3	LM	Sabula drill core	Bone	0.30	Not analyzed															
			411211/783847/1C	1.1	AR	0.7	29.7	54.9	14.7	2.6	4.6	72.5	1.1	4.5	14.7	12,890	2780	2840	2910+	8
					Dry		29.9	55.3	14.8	2.6	4.6	73.0	1.1	3.9	14.8	12,980				
					MAF		35.1	64.9		3.0	5.4	85.7	1.3	4.6		15,230				
			411211/783847/1B	0.65	AR	0.6	27.2	56.0	16.2	1.3	4.5	72.5	1.0	4.5	16.2	12,690	2910+	—	—	4½
					Dry		27.3	56.5	16.2	1.3	4.4	72.9	1.0	4.2	16.2	12,760				
					MAF		32.6	67.4		1.6	5.3	87.0	1.2	4.9		15,240				
			Bone	0.65	Not analyzed															
			411211/783847/1A	0.55	AR	0.4	30.7	55.2	13.7	1.9	4.8	73.8	1.2	4.6	13.7	13,070	2880	2910+	—	8
					Dry		30.8	55.5	13.7	1.9	4.7	74.2	1.2	4.3	13.7	13,130				
					MAF		35.7	64.3		2.2	5.5	85.9	1.4	5.0		15,220				
			Composite of		AR	0.5	26.6	54.3	18.6	2.2						12,200				
			−/1E, −/1D, −/1C,	3.40	Dry		26.7	54.6	18.7	2.3						12,300				
			−/1B, −/1A	(4.35)	MAF		32.9	67.1		2.8						15,100				

[1]Sample condition:
AR—as received
Dry—dried at temperature of 105°C
MAF—moisture and ash free

[2]BTU determinations in composites are to nearest hundred

Table 2. *Published Analyses of Coal as Shipped or Delivered from the Sabula and Penfield Quadrangles*

					Proximate analysis					BTU per pound							
						Dry coal											
Coal bed	Location (adit)	Mine	Size of coal	USBM index no.	Moisture as rec'd	Volatile matter	Fixed carbon	Ash	Sulfur	As rec'd	Dry coal	MAF	Tons delivered	Place of delivery	Date	Ash softening temp. °F	Reference source
Lower Kittanning	Force	Proctor #1	2-in. lump	665	2.2	31.5	58.4	10.1	3.3	13,600	13,900	15,470	—	Tipple	2-4-38	2260	Ashley and others (1939), Table 17, p. 74-75
do.	do.	do.	2-by-4-in. egg	666	1.9	21.1	60.3	8.6	2.5	13,840	14,110	15,440	—	U.S. Army posts, N.Y. & N.H.	1935-36	—	do.
do.	do.	do.	1¼- by 4-in. egg	667	1.9	31.7	58.6	9.7	2.8	13,680	13,950	15,450	—	U.S. Army posts, N.Y. & Vt.	1934-35	—	do.

do.	do.	do.	⅝- by 2-in. nut	668	2.2	31.7	56.8	11.5	3.3	13,330	13,630	15,410	—	Tipple	2-4-38	2290	do.
do.	do.	do.	Nut and slack	669	1.6	31.5	57.2	11.3	3.1	13,340	13,560	15,290	—	Mt. Morris, N.Y.	1935-36	2300	do.
do.	do.	do.	⅝-in. slack	670	3.3	31.0	58.1	10.9	3.1	13,240	13,690	15,370	—	Tipple	2-4-38	2360	do.
do.	Tyler	Proctor #2	Run-of-mine	652	1.5	31.8	59.8	8.4	2.4	13,950	14,160	15,460	—	N.Y.	1934-35	2360	op. cit., p. 72-73
do.	do.	do.	4-in. lump & 50% 1¼-in. nut and slack	653	2.6	30.3	58.7	11.0	3.4	13,370	13,720	15,420	—	Tipple	2-9-38	2280	do.
do.	do.	do.	1- by 4-in. egg	654	2.5	31.4	60.3	8.3	2.7	13,700	14,050	15,320	—	Ft. Devens, Mass.	1935-36	—	do.
do.	do.	do.	Nut and slack	655	2.7	30.9	58.3	10.8	2.8	13,360	13,730	15,390	—	N.Y. and Bath, N.Y.	1931-32	—	do.
do.	do.	do.	1¼-in. nut and slack	656	3.1	30.7	59.2	10.1	3.1	13,410	13,840	15,400	—	Tipple	2-9-38	2350	do.
do.	do.	do.	2 by 5 in.	—	1.7	31.4	59.1	9.5	2.8	13,720	13,960	15,430	4935	N.Y.	1939-40	(5 analyses)	Snyder and Swingle (1942), p. 10

Table 3. *Published Analyses of Mine Samples of Coal from the Sabula and Penfield Quadrangles*

						Proximate analysis				Ultimate analysis						Heat value			
Coal	Location (adit)	Mine	Location in mine	USBM laboratory no.	Sample condition[1]	Moisture	Volatile matter	Fixed carbon	Ash	Sulfur	Hydrogen	Carbon	Nitrogen	Oxygen	Air-dry loss percent	Calories	BTU	Ash softening temp. °F	Reference source
Lower Kittanning	2 miles west of Force	Proctor #1	Face of 4 right heading	75351	1	2.4	31.0	59.9	6.7	2.3	—	—	—	—	1.5	7844	14,120	2310	Ashley and others (1939), Table 20, p. 182–183
do.	do.	do.	Face of 4 left heading	75352	1	2.9	30.7	60.6	5.8	2.0	—	—	—	—	2.1	7861	14,150	2350	do.
do.	do.	do.	Face of 3 right heading	75353	1	2.5	32.0	60.0	5.5	1.8	—	—	—	—	1.7	7939	14,290	2440	do.
do.	do.	do.	Composite of samples 75351 to 75353	75354	1	2.7	30.5	60.9	5.9	2.0	5.3	78.8	1.3	6.7	1.8	7861	14,150	—	do.
					2	—	31.4	62.6	6.0	2.0	5.1	81.0	1.3	4.6	—	8078	14,540	—	do.
					3	—	33.4	66.6	—	2.2	5.5	86.2	1.4	4.7	—	8594	15,470	—	do.
Lower Freeport	DuBois	Clear Run #2	—	833[2]		2.1	31.9	58.1	7.9	3.5	5.1	76.8	1.4	5.3	7[3]	6.6[4]	15,190[5]	2150	Birge and others (1963), Table 5, p. 9

[1] Sample condition:
1—as received at the laboratory
2—dried at temperature of 105°C
3—moisture and ash free

[2] Chemical analyses as carbonized

[3] Free-swelling index

[4] Agglutinating value

[5] Moist mineral-matter free

Crentz and others (1952) reported on the preparation characteristics of coals from Clearfield County for metallurgical use. Coal samples numbered 23 and 24 in that report were samples of the Lower Kittanning coal from the Sabula-Penfield area. The report concluded that this seam would be satisfactory as a general-purpose fuel, but that it would probably not be suitable as metallurgical fuel because of its sulfur content.

Coal Reserves

In calculating the coal reserves in the Sabula-Penfield area, procedures recommended by the U. S. Geological Survey (Averitt, 1969) were used. The reserves are classed in three reliability categories—"measured," "indicated," and "inferred." "Measured" coal includes all coal lying within one-fourth mile of a control point, whereas "indicated" coal lies more than one-fourth mile but less than three-fourths mile from a control point. All remaining reserves are classed as "inferred."

No overburden categories are listed because all coal in the report area has less than 1000 feet of cover. The reserves are reported by township and for that portion of the City of DuBois that lies within the area of the report. Three thickness categories are used: 14 to 28 inches, 28 to 42 inches, and greater than 42 inches. In calculating tonnages, an average weight of 1800 short tons per acre-foot was used.

Reserve estimates for the Lower Kittanning no. 3 coal are listed in Table 4, which shows total reserves of 186 million tons of coal over 14 inches thick, and 150 million tons over 28 inches thick. Plate 7 illustrates the areal distribution and variability of this particular seam, including specific measured sections of the coal.

While data on this seam are sometimes lacking over much of the report area, available information indicates that the Lower Kittanning no. 3 coal is of minable thickness in most of the Sabula-Penfield area. Additional drilling for coal has not gone deep enough in the region of the Punxsutawney-Caledonia syncline to penetrate the Lower Kittanning no. 3 seam, perhaps explaining why it has not been exploited to a greater extent in the past.

Information was either lacking or too limited to permit valid reserve computations on other coals. However, all available measured sections on these coals are shown on Plate 8.

Evidence does indicate that at least some of the other coals are only sporadically developed in the Sabula-Penfield area (see Plate 8). For instance, the Middle Kittanning coal was stripped in the southeastern part of Matley Hollow, where it varied from 3 to 3½ feet in thickness. It measured 2½ to 3½ feet northwest of the village of Penfield. However, it appears to thin in other areas, especially east of Penfield, where drill records show the seam averaging 1 to 1½ feet thick, and some records indicate no coal at that horizon.

Table 4. *Lower Kittanning Coal Reserves in the Sabula and Penfield Quadrangles*

County	Township (or borough)	Area of twp. (bor.) in quad. (acres)	Areas of coal lost by erosion (acres)	Coal over 14″ thick in place before mining (acres)	Mined out and lost (acres)	Coal over 14″ thick remaining (acres)	Category	Coal reserves in tons of 2000 pounds						Total reserves in tons of 2000 pounds			
								14–28″ thick		28–42″ thick		>42″ thick		14″ and more thick		28″ and more thick	
								Acres	Thousands of tons	Acres	Thousands of tons	Acres	Thousands of tons	Acres	Thousands of tons	Acres	Thousands of tons
							measured	19.5	79	2,975.8	14,550	12.9	83	3,008.2	14,712	2,988.7	14,633
Clearfield	Huston	37,356	9,518	27,838	4,417	23,421	indicated	433.4	1,755	7,479.2	38,506	—	—	7,912.6	40,261	7,479.2	38,506
							inferred	5,124.3	20,753	7,375.9	34,771	—	—	12,500.2	55,524	7,375.9	34,771
							TOTAL	5,577.2	22,587	17,830.9	87,827	12.9	83	23,421.0	110,497	17,843.8	87,910
							measured	48.1	195	260.1	1,311	—	—	308.2	1,506	260.1	1,311
	Sandy	16,884	3,812	13,072	181	12,891	indicated	93.5	378	2,592.9	12,713	—	—	2,686.4	13,091	2,592.9	12,713
							inferred	1,207.7	4,891	8,688.7	43,095	—	—	9,896.4	47,986	8,688.7	43,095
							TOTAL	1,349.3	5,464	11,541.7	57,119	—	—	12,891.0	62,583	11,541.7	57,119
							measured	—	—	—	—	—	—	—	—	—	—
	Union	2,514	705	1,809	—	1,809	indicated	—	—	—	—	—	—	—	—	—	—
							inferred	1,175.2	4,760	633.8	2,758	—	—	1,809.0	7,518	633.8	2,758
							TOTAL	1,175.2	4,760	633.8	2,758	—	—	1,809.0	7,518	633.8	2,758
							measured	—	—	—	—	—	—	—	—	—	—
	Pine	4,134	3,998	136	—	136	indicated	—	—	—	—	—	—	—	—	—	—
							inferred	—	—	136.0	591	—	—	136.0	591	136.0	591
							TOTAL	—	—	136.0	591	—	—	136.0	591	136.0	591
	City of						measured	—	—	—	—	—	—	—	—	—	—
	DuBois	320	—	320	—	320	indicated	—	—	—	—	—	—	—	—	—	—
							inferred	—	—	320.0	1,599	—	—	320.0	1,599	320.0	1,599
							TOTAL	—	—	320.0	1,599	—	—	320.0	1,599	320.0	1,599
							measured	67.6	274	3,235.9	15,861	12.9	83	3,316.4	16,218	3,248.8	15,944
TOTALS		61,208	18,033	43,175	4,598	38,577	indicated	526.9	2,133	10,072.1	51,219	—	—	10,599.0	53,352	10,072.1	51,219
							inferred	7,507.2	30,404	17,154.4	82,814	—	—	24,661.6	113,218	17,154.4	82,814
							TOTAL	8,101.7	32,811	30,462.4	149,894	12.9	83	38,577.0	182,788	30,475.3	149,977

Elk	Horton	7,113	6,600	513	13	500	measured	97.7	249	—	—	—	—	97.7	249	—	—
							indicated	331.5	1,095	—	—	—	—	331.5	1,095	—	—
							inferred	70.8	205	—	—	—	—	70.8	205	—	—
							TOTAL	500.0	1,549	—	—	—	—	500.0	1,549	—	—
	Jay	444	228.8	215.2	175	40.2	measured	—	—	—	—	—	—	—	—	—	—
							indicated	—	—	19.2	115	—	—	19.2	115	19.2	115
							inferred	—	—	21.0	120	—	—	21.0	120	21.0	120
							TOTAL	—	—	40.2	235	—	—	40.2	235	40.2	235
	Fox	105	6.3	98.7	88	10.7	measured	—	—	—	—	—	—	—	—	—	—
							indicated	—	—	1.5	9	—	—	1.5	9	1.5	9
							inferred	—	—	9.2	55	—	—	9.2	55	9.2	55
							TOTAL	—	—	10.7	64	—	—	10.7	64	10.7	64
TOTALS		7,662	6,835.1	826.9	276	550.9	measured	97.7	249	—	—	—	—	97.7	249	—	—
							indicated	331.5	1,095	20.7	124	—	—	352.2	1,219	20.7	124
							inferred	70.8	205	30.2	175	—	—	101.0	380	30.2	175
							TOTAL	500.0	1,549	50.9	299	—	—	550.9	1,848	50.9	299
Jefferson	Snyder	3,078	2,416	662	13	649	measured	28.0	71	—	—	—	—	28.0	71	—	—
							indicated	414.8	1,358	—	—	—	—	414.8	1,358	—	—
							inferred	206.2	702	—	—	—	—	206.2	702	—	—
							TOTAL	649.0	2,131	—	—	—	—	649.0	2,131	—	—
GRAND TOTAL		71,948	27,284.1	44,663.9	4,887	39,776.9	measured	193.3	594	3,235.9	15,861	12.9	83	3,442.1	16,538	3,248.8	15,944
							indicated	1,273.2	4,586	10,092.8	51,343	—	—	11,366.0	55,929	10,092.8	51,343
							inferred	7,784.2	31,311	17,184.6	82,989	—	—	24,968.8	114,300	17,184.6	82,989
							TOTAL	9,250.7	36,491	30,513.3	150,193	12.9	83	39,776.9	186,767	30,526.2	150,276

The Lower Freeport coal also apparently exhibits this sporadic development. It has been stripped on Gobbler Knob where it measured 2 to 3 feet thick. However, drill records indicate that this seam rarely is more than a foot thick, and quite often it is nonexistent.

Finally, it should be remembered that these generalizations are based on sparse information, and that these other coals should not be disregarded in future coal explorations. It is apparent that a drilling program should be initiated in order to locate minable reserves that may be present.

CLAY AND CLAY SHALE

There are considerable reserves of clay and clay shale (including claystone) in the Sabula-Penfield area. The clay (underclay) deposits underlie most of the coals and are believed to be more laterally persistent than the coals. The clay shales commonly are found overlying the coals and generally are quite thick, frequently exceeding 10 feet.

To date, there has been only limited use of these clays in ceramic products and of some shales for surfacing material on low-use local roads. Very little has been published on shales and clays of the Sabula-Penfield area. All such published data are included in this report. This part of the report refers only to the potential economic deposits of these materials in the Sabula-Penfield area. Measured sections of the thicker, more persistent and uniform clays, clay shales, and claystones in the report area are listed in Table 5 and are shown on Plate 9.

Table 5. *Thickness and Stratigraphic Position of Clays, Clay Shales, and Limestones in the Sabula and Penfield Quadrangles*

Station	Page number of measured section	Thickness (feet)	Lithology	Stratigraphic position
Cc6	A65–A66	11	Underclay	Federal Hill-Duquesne
Bc3	A63	9	Underclay	Harlem
Cc4	A70	27.5	Claystone	Harlem
Cc6	A65–A66	38+	Claystone	Harlem
Bc7	A64	15	Plastic clay	Lower Bakerstown
Aa3	A54–A55	7.5	Claystone	Upper Freeport
Bb35	A70	1.5	Claystone	Upper Freeport
Bb35	A70	13	Clay shale	Upper Freeport
Ab5	A52–A53	5.5	Underclay	Lower Freeport
Bb23	A53–A54	4.5+	Underclay	Lower Freeport
Bb23	A53–A54	6.7	Clay shale	Lower Freeport

Table 5. *(Continued)*

Station	Page number of measured section	Thickness (feet)	Lithology	Stratigraphic position
Ac12	A51	3+	Underclay	Upper Kittanning
Aa11	A43–A44	4+	Underclay	Middle Kittanning
Ab8	A70	4.7	Underclay	Middle Kittanning
Bb21	A70	6.5	Underclay	Middle Kittanning
Bb10	A45–A46	5	Underclay	Middle Kittanning
Ec5	A70	20+	Underclay	Lower Kittanning
Bc1	A70	20.1	Underclay	Lower Kittanning
Bc1	A70	5.8	Claystone	Lower Kittanning
Cb13	A65	15	Clay shale	Barton
Bc6	A64	19.7	Clay shale	Harlem
Bc5	A63	23+	Clay shale	Pittsburgh(?) red beds
Cc1	A65	29	Clay shale and claystone	Pittsburgh(?) red beds
Cb14	A71	20+	Clay shale	Pittsburgh(?) red beds
Cb9	A65	11+	Clay shale	Meyersdale red beds
Bc7	A64	15	Clay shale	Lower Bakerstown
Ac31	A61	10.5+	Clay shale	Cambridge
Da47	A71	17.5+	Clay shale	Cambridge
Bb15	A61–A62	39+	Clay shale	Brush Creek(?)
Ac26	A60–A61	25+	Clay shale-silt shale	Brush Creek
Db2	A71	30±	Clay shale	Brush Creek
Eb1	A71	10	Claystone	Mahoning(?)
Ea6	A54	11	Clay shale	Upper Kittanning
Fb2	A47–A48	30	Clay shale	Middle Kittanning
Ac2	A44	20	Clay shale	Lower Kittanning
Bb7	A71	11	Clay shale	Lower Kittanning
Da11	A71	20±	Clay shale	Lower Kittanning
Da2	A46	11.5	Clay shale	Lower Kittanning
Da43	A71	12.8	Clay shale	Lower Kittanning
Da47	A72	10.6	Clay shale	Lower Kittanning
Fa6	A72	8+	Clay shale	Lower Kittanning
Fa6	A72	16.5	Silt shale	Lower Kittanning
Fb2	A47–A48	20	Clay shale	Lower Kittanning
Bb36	A72	9	Claystone-limestone	Johnstown
Ac11	A55–A56	1.5	Limestone	Upper Freeport(?)
Aa3	A54–A55	4	Limestone	Upper Freeport
Aa8	A60	3±	Underclay with limestone	Upper Freeport(?)
Ac26	A60–A61	1.5	Limestone	Brush Creek
Bb27	A62–A63	2	Limestone	Brush Creek
Cc6	A65–A66	3.5	Siltstone with limestone	Ames

Section descriptions of Conemaugh clays and vertically adjacent units are given in Appendix 6, p. A63-A66 (Bc3, units 1-2; Bc7, units 1-5; Cc6, units 1-2 and 10-12) and in Appendix 7, p. A70 (Cc4). Sample #249 in Leighton (1941) was a 24-foot sample of clay beneath the Harlem coal (Leighton mistakenly lists this coal as a coal underlying the Brush Creek limestone) and was exposed at a railroad tunnel at Sabula. This clay was tested and found to have fair plasticity and green strength, but had a low fusion point of cone 9, which would make it of doubtful value. Firing tests and other physical tests on 3.8 feet of clay below the Cambridge-Pine Creek marine zone from the Sabula drill hole (Cb3, Appendix 3) are shown in Appendix 8, sample 74A-13.

Good exposures of the interval below the Mahoning coal are rare in the report area. The Pennsylvania Railroad drill hole (Bc1, Appendix 4) showed more than 10 feet of claystone underlying the Mahoning coal horizon. The section at Bb35 showed about 15 feet of clay shale immediately above the Upper Freeport coal.

Measured sections of the clays and claystones and vertically adjacent units underlying the Upper Freeport coal are included in Appendix 5, p. A55 (Aa3, units 7-9) and in Appendix 7, p. A70 (Bb35). Other exposures of the Upper Freeport clay were found at Cc16, where 2 feet of soft underclay was seen, and at Eb22 in the Penfield 7½-minute quadrangle, where 4 feet of clay was exposed. The Pennsylvania Railroad drill record (Bc1, Appendix 4) showed more than 5 feet of underclay and claystone under the Upper Freeport coal. In the drill holes at Da43 and Da47, there were 6.1 feet and 5.3 feet, respectively, of claystone underlying this coal. In the Sabula drill hole (Cb3, Appendix 3), there was 3.7 feet of claystone below the Upper Freeport coal. Firing tests and physical data on 9.25 feet of claystone/clay shale from this interval are shown in Appendix 8, sample 74A-14.

Measured sections at Ab5 (Appendix 5, p. A52, units 5-6) and Bb23 (Appendix 5, p. A53, units 11-14) show the nature of the rocks underlying the Lower Freeport coal in the Sabula-Penfield area. Firing tests and physical data on 2.9 feet of silt/clay shale below the Lower Freeport coal in the Sabula drill core (Cb3, Appendix 3) are given in Appendix 8, sample 74A-15. At Ea6, up to 3 feet of Lower Freeport underclay was exposed in a gas well site. The clay was soft and plastic and contained some limestone nodules. Another exposure of the same unit was seen at Ac11 where 7½ feet of olive-gray underclay was measured. This clay was soft and nonfissile and contained some freshwater limestone nodules and a thin layer of coal near the base. At Da43, there were 8.3 feet of claystone and 4.1 feet of clay shale underlying a thin coal which may be the Lower Freeport coal.

Information on the clays associated with the Upper Kittanning coal horizon is limited in the report area. Two feet of underclay below the

Upper Kittanning coal was seen at Ab9 and Bb23. In the Pennsylvania Railroad drill hole (Bc1, Appendix 4), there was more than 11 feet of underclay and claystone underlying the Upper Kittanning coal. In the drill holes at Da43 and Da47, there were 12.0 feet and 5.8 feet, respectively, of claystone at this horizon. A detailed measured section of the Upper Kittanning interval is included in Appendix 5, p. A51 (Ac12, units 1-2).

Because of increased mining activity on the Middle and Lower Kittanning coals, exposures of the Middle Kittanning clay were more numerous in the report area. This clay appears to be fairly well developed and persistent. Several sections which show the general character of this and vertically adjacent units are given in Appendix 5, p. A43 and A45 (Aa11, unit 9; Bb10, units 10-12) and in Appendix 7, p. A70 (Ab8; Bb21). Firing tests and physical data on 4.7 feet of claystone below the Middle Kittanning coal in the Sabula drill core (Cb3, Appendix 3) are given in Appendix 8, sample 74A-16. The Middle Kittanning clay was also seen at Da2, Da7, Fb2, Eb39, and Ec4. The clay averaged 2 to 3 feet in thickness in these exposures. The same interval in the Pennsylvania Railroad drill core (Bc1, Appendix 4) included more than 9 feet of underclay and claystone. Three and one half feet of claystone below the Middle Kittanning coal was measured in the drill hole at Da43, and 4.7 feet of claystone from the same interval was found in the drill hole at Da47.

Although exposures are limited, the clays below the Lower Kittanning no. 3 coal appear to have the thickest development of any of the clays in the report area. Descriptions of the more complete sections are given in Appendix 7, p. A70 (Ec5; Bc1). An analysis of a sample of 20+ feet of clay from the mine at Ec5 is shown in Appendix 8, p. A73. Firing tests and physical data on a 20-foot channel sample of clay from the same mine are listed in Appendix 8, sample 74A-21. Firing tests and physical data on two samples from the Lower Kittanning underclay complex in the Sabula drill core (Cb3, Appendix 3) are given in Appendix 8 (samples 74A-17 and 74A-18).

Two selected samples from the Lower Kittanning no. 3 underclay complex in the Sabula drill hole were analyzed semiquantitatively by X-ray at the Pennsylvania Geological Survey. At 477.4 feet in the core, quartz and kaolinite occur in about equal proportions (quartz, 45-55 percent, and kaolinite, 45-55 percent) and muscovite is noticeably absent. At 478.4 feet, siderite dominates the mineralogy (85-95 percent); kaolinite and quartz each range between 1 and 5 percent. Again, muscovite is absent—an unusual feature in comparison with other underclays in Pennsylvania analyzed by the Geological Survey.

In the drill hole at Da47, 5.5 feet of claystone below the Lower Kittanning coal was measured. In the drill hole at Da43, 6.0 feet of claystone below the Lower Kittanning coal was measured, below which was found 6.2 feet of clay shale with possible diaspore in the lower 2 feet.

The Lower Kittanning clay is presently being mined to the west of the report area in the adjacent Falls Creek quadrangle at DuBois Fb1 (see Plate 1). Information on a sample of clay from this mine has been published in the Pennsylvania Survey's Mineral Resource Report 51 (O'Neill and others, 1965) and is included in Appendix 8, sample 64-3-1.

According to Leighton (1941), the Lower Kittanning clay has been tested in several mines from the area around Penfield and Tyler. In all cases, the clay has been of questionable quality or too thin to be of economic value. Leighton also states that some shales and thin clays along the railroad west of Tyler would be suitable for the manufacture of brick. These units were from the Middle and Upper Kittanning horizons.

Information on the clays associated with the Clarion coals in the Sabula-Penfield area is limited to two drill records, the Pennsylvania Railroad drill hole at Bc1, and the Sabula hole at Cb3. Logs of both of these records are included in Appendices 3 and 4 of this report. Firing tests and physical data on two samples of the clay complex below the Clarion no. 2 coal in the Sabula core (Cb3) are given in Appendix 8 (samples 74A-19 and 74A-20).

Shale (including claystone) is one of the more common rock lithologies found in the report area. The thicker and more uniform units are found over the major coals in the Allegheny Group as well as throughout the Conemaugh Group.

Leighton (1941) reports that 33 feet of shale above the Ames Limestone (called Brush Creek by Leighton) at the Sabula tunnel was tested. The sample had good plasticity and fair green strength, fired red to brown with a firing range from cone 010 to cone 06, and is believed to be suited for the manufacture of face brick or hollow tile.

The locations and thicknesses of the better exposures of shale in the Conemaugh Group are listed in Table 5. Detailed descriptions of the exposures are included in Appendix 6, p. A61-A65 (Ac26, units 4-6; Ac31, units 3-4; Bb15, units 3-5; Bc5, units 3-6; Bc6; Bc7, units 5-7; Cb9, units 3-6; Cb13; Cc1) and in Appendix 7, p. A71 (Cb14; Da47). In the drill hole at Da43, there was 15.5 feet of clay shale immediately overlying the Brush Creek marine zone. This shale was medium dark to dark gray and contained a few small pyrite blebs. Other measured sections of the units overlying the Brush Creek marine zone are given in Appendix 7, p. A71 (Db2; Eb1). There are also relatively thick clay shale and claystone units that overlie the Brush Creek and Cambridge-Pine Creek marine zones and underlie the Lower Kittanning and Mahoning coal horizons in the Sabula drill hole (Cb3, Appendix 3).

Locations and thicknesses of potential economic deposits of clay shale and claystone in the Allegheny Group from the Sabula-Penfield area are

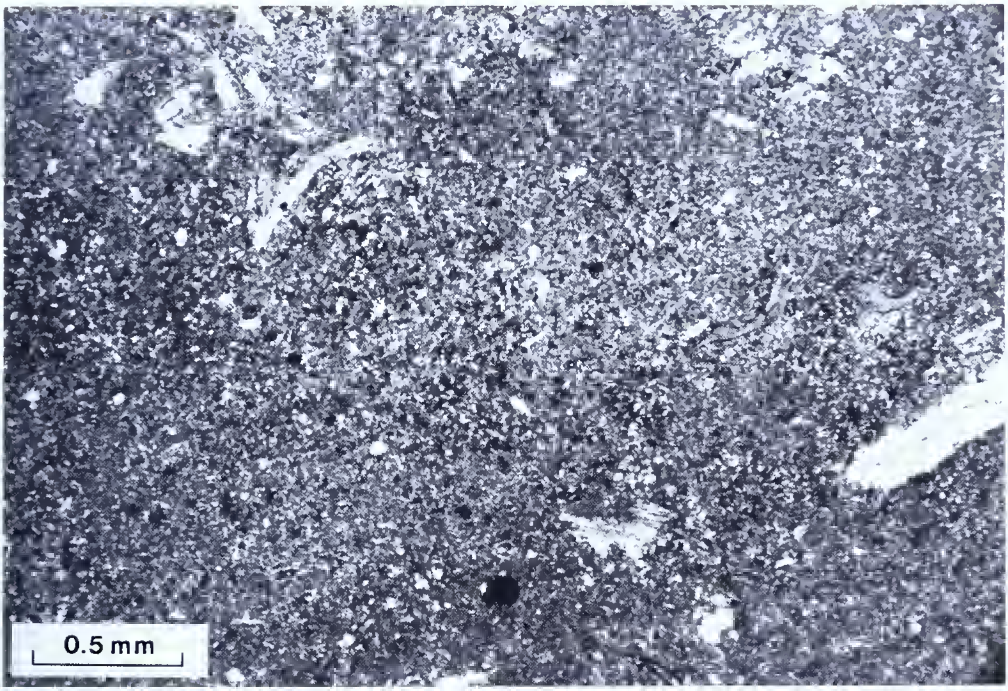

Figure 18. Photomicrograph of thin section of Vanport Limestone from 510.5 feet in the Sabula drill hole at station Cb3. Note fine, dark pellets and fossil invertebrate shell fragments. Plane-polarized light.

given in Table 5 and shown on Plate 9. Descriptions of the intervals are given in Appendix 5 (Ac2, units 2-4, p. A44; Da2, units 2-4 and 6-7, p. A46; Ea6, units 2-7, p. A54; Fb2, units 2-4 and 6-7, p. A47) and in Appendix 7, p. A71-A72 (Bb7; Da11; Da43; Da47; Fa6).

LIMESTONE

Limestones are not well developed in the Sabula and Penfield quadrangles. The surface stratigraphic occurrences (Table 5) are limited to the Allegheny and Conemaugh Groups. The Johnstown Limestone, a freshwater limestone below the Upper Kittanning coal, and the freshwater limestones beneath the Upper and Lower Freeport coals represent the best developed horizons based on the authors' field observations. Although the Vanport Limestone (in the Clearfield Creek Formation) was seen only in the Sabula drill hole (Cb3), it may be widely developed, but thin. Limestone horizons in the Conemaugh Group include the Mahoning(?), Brush Creek, Cambridge-Pine Creek, Albright, and Ames; these are usually calcareous siltstones, but may occasionally grade laterally into argillaceous limestone.

The Vanport Limestone (Figures 18 and 19) is 1.5 feet thick in the Sabula drill hole and is a pelletiferous micrite (limestone classification

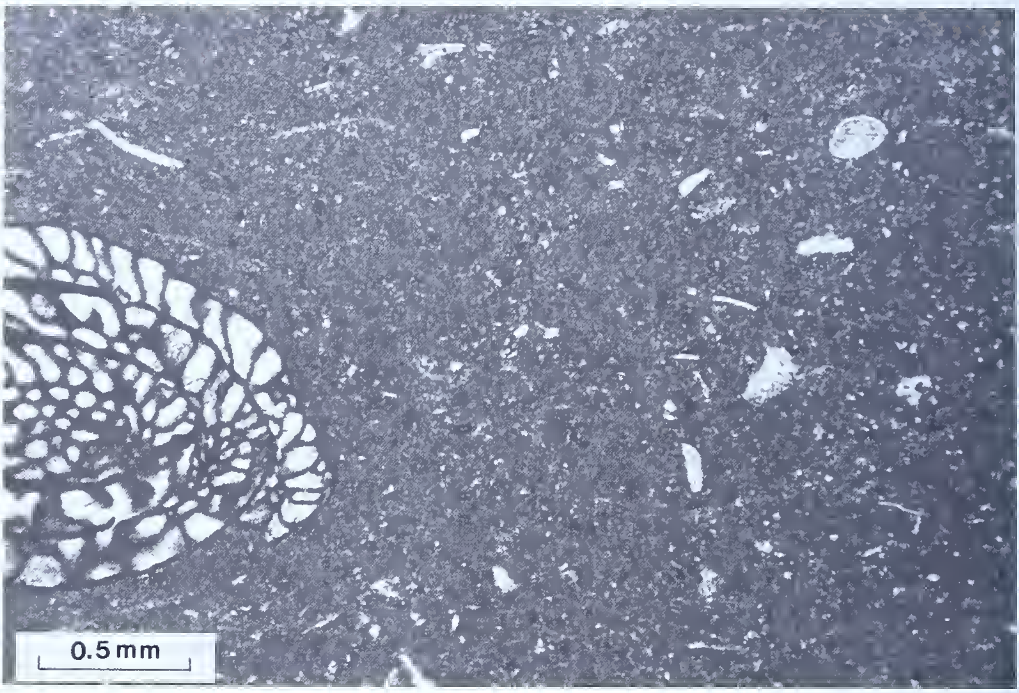

Figure 19. Photomicrograph of thin section of Vanport Limestone from 511.2 feet in the Sabula drill hole at station Cb3. Note fusilinid (left) and other fossil fragments in micrite matrix. Plane-polarized light.

of Folk, 1962, p. 70), bearing some ostracode, fusulinid, and other micro- and macrofossil fragments. Although the Vanport Limestone was not found in outcrop in the Sabula-Penfield area, it is well developed in adjacent quadrangles to the north and west of this report area. The Johnstown Limestone (Figure 20) is a component of the thick underclay complex below the Upper Kittanning coal in the Sabula drill hole. Microscopic analysis of the Johnstown from that core indicates that it is an ostracode and *Spirorbis*-bearing micrite or pelletiferous micrite with minor amounts (5± percent) of fine quartz silt. Some grain-growth enlargement of the micrite is evident. The Johnstown Limestone at Bb36 consists of 9 feet of claystone-limestone complex underlain by 10 feet of hard claystone. For a detailed description of this section, see Appendix 7, p. A72. At Da14, the Johnstown Limestone has an acid-insoluble residue of 37.0 percent.

The limestone below the Lower Freeport coal at Ab4 is an integral part of the Lower Freeport underclay. It is medium dark gray, weathering to pale yellowish orange, and bears small, silicified, tube-like structures which are probably fossil freshwater algae (Charophycophyta). Two limestone samples from this site were analyzed for their acid-

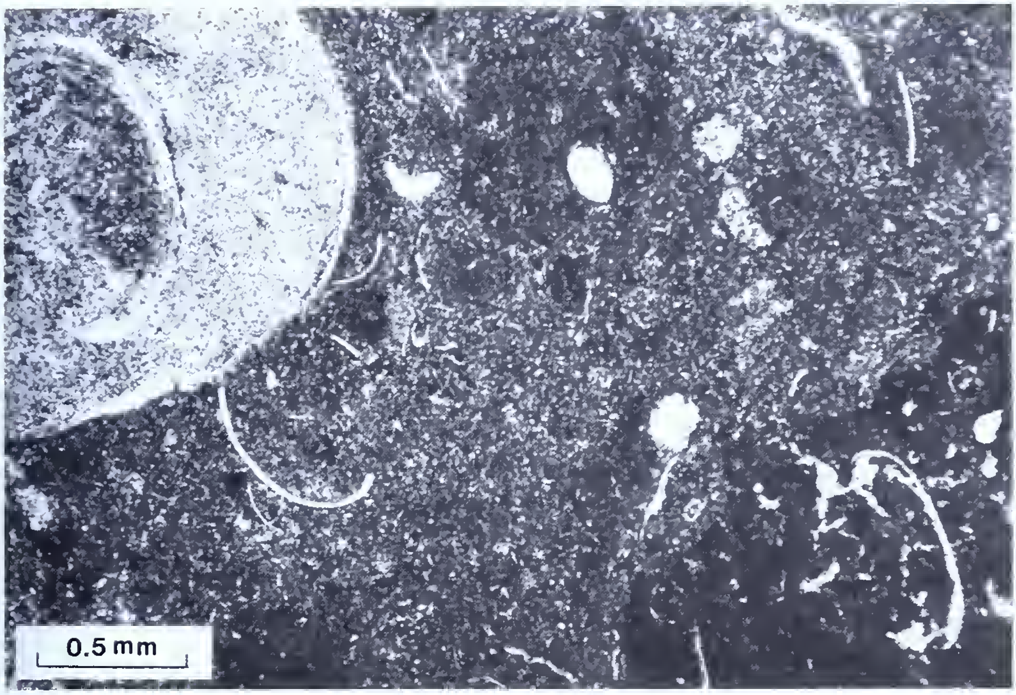

Figure 20. Photomicrograph of thin section of Johnstown Limestone from 321.3 feet in the Sabula drill hole at station Cb3. Note large *Spirorbis* at upper left and ostracode fragments in argillaceous micrite matrix. Plane-polarized light.

insoluble residue. One sample has a residue of 15.8 percent; the other has a residue of 4.4 percent.

A 1.5-foot limestone above the Lower Freeport coal is exposed at Ac11. That this is the Upper Freeport limestone is in question. The freshwater limestone may be part of an underclay complex below a Lower Freeport rider coal horizon. The detailed description of this exposure is given in Appendix 5, p. A55-A56. The limestone at this site has an acid-insoluble residue of 45.6 percent.

Four feet of the Upper Freeport limestone is exposed at Aa3 in an abandoned strip mine. A detailed description of this exposure is given in Appendix 5, p. A54-A55.

A limestone horizon (Mahoning?) occurs in the sedimentary cycle overlying the Upper Freeport coal on the northwestern flank of the Boone Mountain anticline near Brockway. A sample collected from spoils of a backfilled Upper Freeport coal stripping at DuBois Fa1 yielded an acid-insoluble residue of 16.9 percent. A poorly exposed section at Aa8 includes freshwater limestone above the Upper Freeport coal. This measured section is given in Appendix 6, p. A60.

The Brush Creek limestone horizon crops out at scattered localities in the Sabula quadrangle. In the Sabula drill hole, there are two very similar marine zones (see Appendix 3) in the approximate stratigraphic positions (120 feet and 190 feet above the Upper Freeport coal) for the Brush Creek and the Cambridge-Pine Creek, but they are not limestones. The same is true in the Pennsylvania Railroad drill hole (Appendix 4, Plate 5), where the Brush Creek and Cambridge-Pine Creek marine zones are siltstones and not limestones, and the Vanport horizon is thin, black, very fossiliferous shale. However, the thin limestone at the top is believed to be equivalent to the Albright, and there is a shaly limestone below the Brush Creek coal and claystone in this hole. At isolated exposures in this report area, miscorrelation of marine zones in this part of the Conemaugh Group is a possibility. Greatly needed regional stratigraphic studies of the Conemaugh will delineate more clearly the marine zones that have been called "Brush Creek" in this area. At Ac26, 1.5 feet of gray argillaceous limestone was noted below the Brush Creek marine zone in a fresh cut on Interstate Route 80. In 1966, this section was well exposed, and a description of the exposure is given in Appendix 6, p. A60-A61. At Bb27, 2 feet of limestone below the Brush Creek marine zone was exposed. This section is described in Appendix 6, p. A62-A63. A similar limestone below the Cambridge-Pine Creek marine zone in the Sabula drill hole at Cb3 (see Appendix 3) yielded an insoluble residue of 39.6 percent.

At Cc6, the Ames marine zone, which included some limestone nodules, was exposed at the eastern portal of the Penn Central Railroad tunnel. A description of this exposure is given in Appendix 6, p. A66 (units 1-7). As with the Brush Creek marine zone, there is the possibility that the Ames may grade laterally into a limestone. These calcareous siltstones in the Conemaugh Group may be of some future value. Where a source of carbonate is desired, transportation costs for pure limestone are high, and chemical prerequisites are not narrow, the calcareous siltstones may be worth consideration.

CONSTRUCTION MATERIALS

Crushed Sandstone

The oldest exposed rocks in this area are included in the Mississippian Pocono Formation, as noted in the section on surface stratigraphy. The Pocono is divided into three units, two of which include sandstone: the lower complex of sandstone, siltstone, and shale; and the upper unit called the Burgoon Sandstone.

Exposures of the lower complex are limited, the best occurring in the Wilson Run roadcuts along Pa. Route 153 as it goes up Boone Mountain (detailed measured sections are given in Appendix 2).

The extent of the Burgoon Sandstone is believed to be limited to the southeastern portion of the report area. However, exposures here are poor because of masking by soil and float. The unit reaches a maximum thickness of 120 feet.

Pottsville sandstones are common on Boone Mountain, although seen mainly as large float blocks. This sandstone sequence varies from medium to very coarse grained and contains lenses of granule and pebble conglomerate. This unit may serve well as a source for ganister mix, furnace bottom sand, and molding sand. The best exposure is at Ca18 where a "rock city" has developed (Figure 7). Other good exposures are at Ba13, Ba15, Ba20, Ba23, Ca2, Ca6, Ca13, Ca17, Da38 (Figure 8), Fb20 (Figure 3), and Fb21.

Other sandstones in the area include the Kittanning, the Freeport, the Butler, and the lower Mahoning. Exposures of these units are noted in the section on stratigraphy in this report. They undoubtedly exhibit sporadic development throughout the area.

All of these sandstone units are potential sources of crushed stone for use in road metal, railroad ballast, riprap, concrete aggregate, and random fill. Some units are quartzitic enough to be considered potential sources of industrial silica for refractory use.

Siltstone and Silt Shale

Siltstone and silt shale constitute the great bulk of the surface rocks of this area. The Pocono Formation (sub-Burgoon), the Allegheny Group, and particularly the Conemaugh Group are all potential sources of siltstone and silt shale. These lithologies frequently may be obtained directly from strip-mine spoil piles. These rocks generally compact well, and have a high bearing strength and low water absorption. For those reasons, these materials are generally well suited for use as road metal, for road fill on low-use secondary roads, and for random fill.

Silt shale has been quarried at Bb47 in the 30-foot sequence over the Brush Creek(?) marine zone. Nearby borrow pits in Conemaugh siltstone are located along the township road near well Bb33. Near the southern border of the Sabula quadrangle along Pa. Route 255, the silt shale beneath the Cambridge-Pine Creek horizon in the Conemaugh has been quarried at several places (Ad1, 4, 5, and 18 in Edmunds and Berg, 1971). The basal portion of the Conemaugh just above the Upper Freeport coal has been quarried for silt shale at Eb32. A borrow pit in shale of the Laurel Run Formation was opened at Dc11. Near Anderson Creek at Ec20, silt shale from the Clearfield Creek Formation has been quarried sporadically for more than twelve years.

Sand and Gravel

Slightly more than six percent of the total area covered by this report has been mapped as Quaternary alluvium. These alluvial deposits range up to approximately 50 feet thick and are spread over flat valley floors that attain widths in places exceeding 1500 feet. The relict floodplains of Bennett Branch, Sandy Lick Creek, and Little Toby Creek are the sites of major, thick alluvial deposition. Minor amounts of alluvium have been mapped, partly by photogeologic interpretation, in most of the minor tributaries. In the upper reaches of secondary streams, the mapped alluvium may be on the order of 2 feet thick.

These deposits include a generally heterogeneous mixture of unconsolidated gravel, sand, and mud. Occasional concentrations of organic matter, as much as 10 feet thick, occur in cut-off meanders. Along Little Toby Creek, at Aa1 (Figure 21), up to 20 feet of alluvium is quarried sporadically for municipal use, probably as random fill material and possibly for use in some concrete mixing. Two channel samples taken at this site were analyzed for grain size distribution; the results are shown in Figure 22. It should be noted that occasional cobbles (Figure 23) and

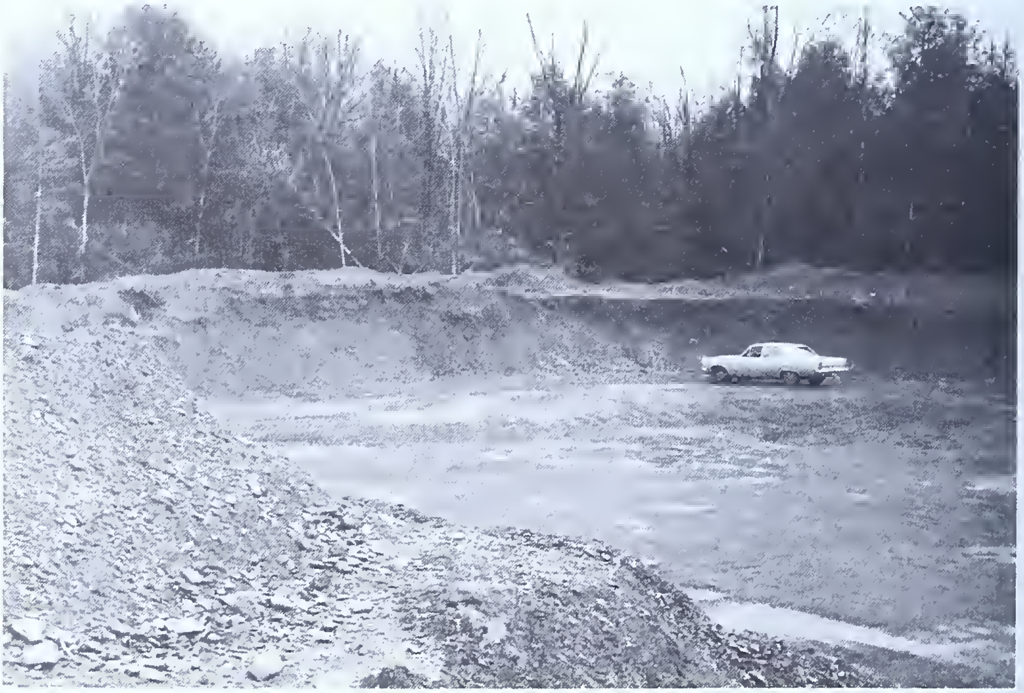

Figure 21. Sand and gravel pit (upper level) in Quaternary alluvium along Little Toby Creek at station Aa1.

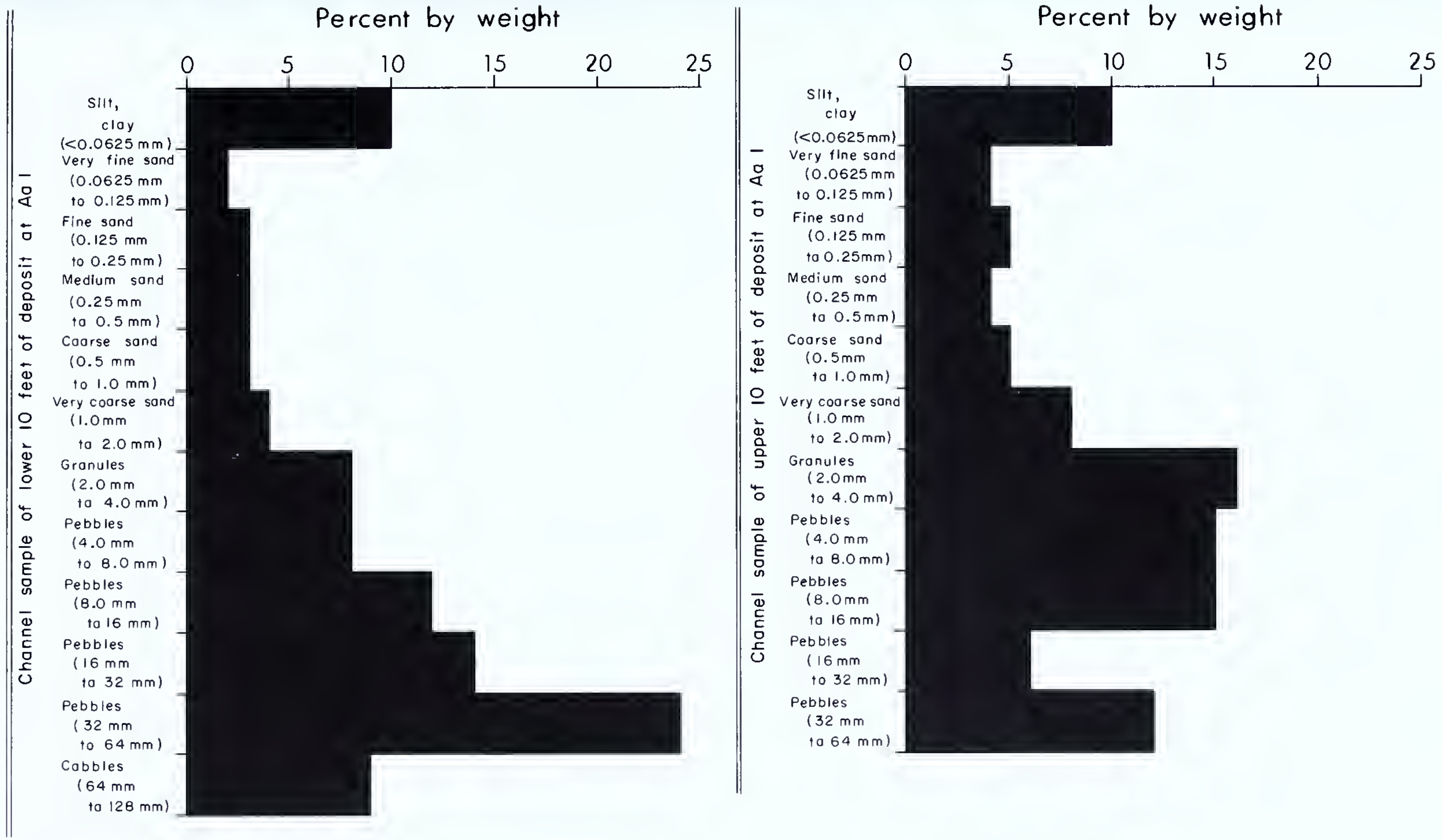

Figure 22. Sediment size distribution in Quaternary alluvium along Little Toby Creek at station Aa1.

rare boulders occur in these deposits. The alluvial material sampled along Little Toby Creek is obviously all locally derived, reflecting dominant bedrock lithologies of the surrounding watershed. The composition of the mean bed load fraction is as follows:

	Percent by weight
Sandstone	50.3
Siltstone and silt shale	37.4
Clay shale and claystone	10.3
Siderite and hematite fragments	1.4
Coal, bone, and coaly shale	0.6

The gravel fragments are generally subrounded and platy to very platy.

NATURAL GAS

General

The Sabula-Penfield area produces a considerable amount of natural gas, giving the area a second valuable fossil fuel resource in addition to coal. The deep producing pools in this area include all of the Sabula pool, most of the Boone Mountain pool, and portions of the Rockton

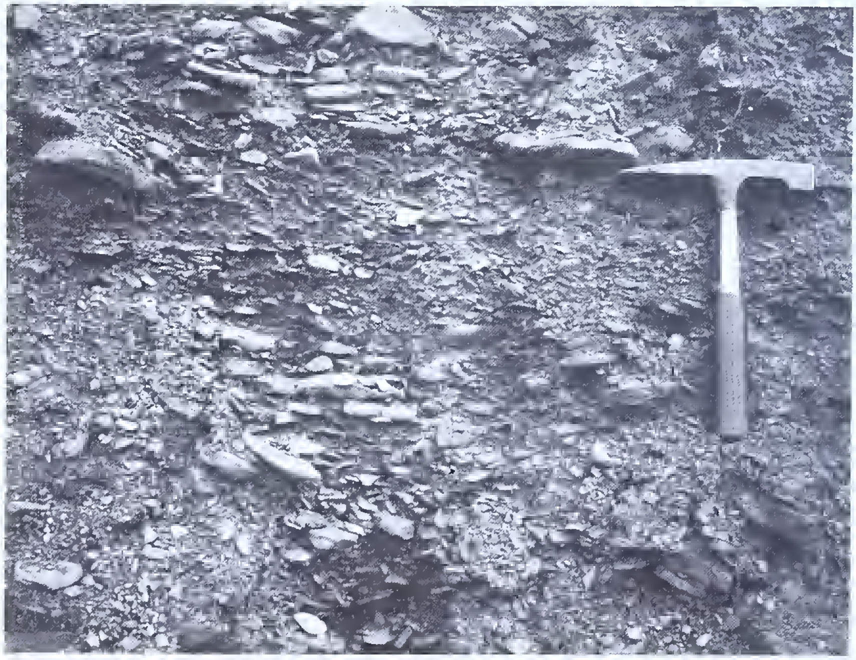

Figure 23. Alluvium in upper level of sand and gravel pit along Little Toby Creek at station Aa1. Note cobble-sized material and dominantly platy shape of fragments.

and DuBois pools. Shallow gas wells are confined to the Boone Mountain field and to the Hollywood pool, located in the area north of the town of Penfield.

Deep gas-producing horizons include the Onondaga Formation and "Oriskany" Sandstone. Shallow production is from Upper Devonian sands.

The Boone Mountain shallow field is depleted and is presently being used as a gas storage area. Lytle (1963, p. 21) reports that the Fifth Venango sand provides a stratigraphic trap for the stored gas.

Tables 6 and 7 of this report list all deep and shallow wells in the Sabula and Penfield quadrangles. The locations of all wells for which information was available are shown on Plate 1. The outlines of the various gas fields and pools may be found on Figure 16, which also shows deep faulting, fold axes, and structure contours on the "Oriskany" Sandstone based on the work of Cate (1961).

Factors Controlling Gas Accumulation

Lytle and others (1959, p. 6) state that the deep gas production in this area is controlled both by structure and stratigraphy, but is primarily related to the existence of stratigraphic traps. Edmunds and Berg (1971) note the occurrence of dry wells along the downthrown side of reverse faults in the southern Penfield area and suggest that this faulting has exerted some influence on gas accumulation there.

Structural influence on the depositional pattern of the Ridgeley ("Oriskany") Sandstone is also indicated by the fact that the thick accumulation of this sandstone is found along the axis of the Punxsutawney-Caledonia syncline, whereas the same unit thins toward the flanking anticlines (Lytle and others, 1960, p. 10).

It is apparent, therefore, that both structure and stratigraphy have influenced the accumulation of gas in the Sabula-Penfield area.

Producing Horizons

Onondaga-Ridgeley ("Oriskany") Interval (Deep Well Production)

The Onondaga chert (Onondaga Formation, Middle Devonian) and the immediately underlying Ridgeley Sandstone of the Oriskany Group (Lower Devonian) constitute the major producing zone in this area. The Onondaga chert averages 40-80 feet in thickness and the Ridgeley Sandstone averages 10-20 feet.[1]

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[1] In subsurface oil and gas terminology the term "Oriskany" refers to the Ridgeley Sandstone only because of the difficulty in differentiating the lower member of the Oriskany Group (Shriver) from the underlying Helderberg Formation.

Table 6. *Deep Natural Gas Wells in the Sabula and Penfield Quadrangles*

Pool	Pa. Geol. Survey, Oil & Gas Div., Penfield 15-min. qd. ref. no.	This report, station no.	Well name	Operator	Date completed	Initial production (Mcfd) or status[1]
—	10	Fb29	W. M. Reiter 1	Godfrey L. Cabot, Inc.	10/10/55	Show
—	11	Ca5	Logan L. Bond 1	NYSNG Corp.	3/25/57	Show; see Table 7
Rockton	29	Ec14	Pa. Tract 63, No. 1	NYSNG Corp. (N505)	12/12/56	6,981
do.	36	Dc13	Whitney Realty Co. 1	Lomega Exploration, Ltd.	5/31/57	1,650
do.	45	Ec11	Pa. Tract 63, No. 2	NYSNG Corp. (N528)	3/1/57	3,243
do.	46	Ec10	Pa. Tract 63, No. 3	NYSNG Corp. (N534)	2/23/57	4,800
do.	47	Ec13	Helen D. S. Gordon 1	NYSNG Corp. (N540)	2/23/57	1,750
do.	50	Ec18	Pa. Tract 63, No. 4	NYSNG Corp. (N535)	3/28/57	4,115
do.	51	Ec15	Whitney Realty Co. 3	Swan & Finch Gas Dev. Co.	4/5/57	3,393
do.	52	Dc10	Whitney Realty Co. 2	Rockton Drilling Co.	4/30/57	3,600
do.	55	Ec9	Helen D. S. Gordon 2	NYSNG Corp. (N558)	5/19/57	3,600
do.	63	Dc14	Vasbinder 1	Swan & Finch Gas Dev. Co.	7/6/57	771
do.	64	Dc12	Whitney Realty Co. 5	Lomega Exploration, Ltd.	7/4/57	4,547
do.	66	Dc15	Sure Shot Land & Gun Club 1	The Sylvania Corp.	7/27/57	976
do.	67	Ec17	Whitney Realty Co. 4	Lomega Exploration, Ltd.	7/26/57	1,200
—	75	Cc19	Pa. Tract 93, No. 1	NYSNG Corp. (N560)	10/10/57	Show
Rockton	78	Cc17	W. Miller 1	Harry Brunt	9/17/57	65,000
do.	81	Eb49	Gordon & Reiter 1	Godfrey L. Cabot, Inc.	9/20/57	6,316
do.	86	Cc18	Pa. Tract 93, No. 2	NYSNG Corp. (N577)	11/1/57	11,401
—	90	Eb38	Green Glen 1	Manufacturers Light & Heat Co.	12/23/57	Show
Rockton	91	Ec2	Helen D. S. Gordon 3	NYSNG Corp. (N573)	10/15/57	6,800
do.	92	Ec19	Pa. Tract 63, No. 5	NYSNG Corp. (N572)	10/15/57	267

do.	93	Cc9	Baker Run Reserve 1	F. C. Deemer	10/19/57	13,500
—	96	Cc10	C. G. Schwem 1	NYSNG Corp. (N579)	12/20/57	Show
Rockton	97	Cc12	Jesse U. Weber 1	NYSNG Corp. (N580)	11/12/57	4,597
do.	103	Ec3	Pudlo Camp 1	Keta Gas & Oil Co.	12/6/57	3,100
do.	104	Cc7	Baker Run Reserve 2	F. C. Deemer	12/14/57	1,875
do.	107	Eb48	Gordon & Reiter 2	Godfrey L. Cabot, Inc.	12/27/57	7,000
do.	109	Fb27	Pa. Tract 49, No. 1	NYSNG Corp. (N604)	1/15/58	12,063
do.	110	Dc7	Baker Run Reserve 3	F. C. Deemer	12/30/57	15,000
do.	112	Cc13	Green Glen 1	NYSNG Corp. (N614)	12/31/57	1,600
do.	118	Eb47	Pa. Tract 76, No. 1	Manufacturers Light & Heat Co.	2/26/58	4,700
do.	119	Eb50	Helen D. S. Gordon 4	NYSNG Corp. (N622)	3/6/58	6,851
do.	120	Cc8	Baker Run Reserve 4	F. C. Deemer	3/3/58	1,850
do.	122	Fb26	Pa. Tract 49, No. 2	NYSNG Corp. (N627)	3/17/58	830
do.	123	Fb25	Pa. Tract 76, No. 2	Manufacturers Light & Heat Co.	4/8/58	7,038
do.	125	Cc11	C. G. Schwem 2	NYSNG Corp. (N603)	4/1/58	1,802
do.	127	Eb52	Helen D. S. Gordon 5	NYSNG Corp. (N621)	4/21/58	3,755
do.	128	Fb23	W. M. Reiter 2	Godfrey L. Cabot, Inc.	3/14/58	3,100
do.	129	Fb24	Pa. Tract 49, No. 3	NYSNG Corp. (N631)	5/3/58	858
do.	130	Fb22	Pa. Tract 76, No. 3	Manufacturers Light & Heat Co.	5/6/58	3,221
—	134	Db4	Green Glen 2	do.	5/29/58	Dry
—	135	Dc4	Baker Run Reserve 5	F. C. Deemer	7/26/58	Show
—	136	Dc1	Baker Run Reserve 6	do.	5/29/58	Dry
Rockton	137	Ec7	Jas. Brundridge 1	Godfrey L. Cabot, Inc.	4/14/58	80
do.	138	Fb28	Pa. Tract 49, No. 4	NYSNG Corp. (N642)	5/26/58	1,378
do.	139	Fb19	Pa. Tract 76, No. 4	Manufacturers Light & Heat Co.	6/4/58	12,800
do.	142	Ec1	Helen D. S. Gordon 6	NYSNG Corp. (N641)	6/19/58	2,877
do.	143	Fc1	Pa. Tract 77, No. 1	NYSNG Corp. (N639)	8/27/58	48
do.	144	Dc5	Baker Run Reserve 7	F. C. Deemer	7/10/58	3,000

Table 6. *(Continued)*

Pool	Pa. Geol. Survey, Oil & Gas Div., Penfield 15-min. qd. ref. no.	This report, station no.	Well name	Operator	Date completed	Initial production (Mcfd) or status[1]
Boone Mt.	148	Da31	Pa. Tract 65, No. 1	NYSNG Corp. (N667)	8/19/58	6,501 Discovery well
do.	149	Da17	Pa. Tract 66, No. 1	NYSNG Corp. (N660)	8/25/58	311
—	152	Dc8	Baker Run Reserve 8	F. C. Deemer	11/1/58	Dry
Boone Mt.	153	Da32	A. J. Palumbo 2	NYSNG Corp. (N678)	10/21/58	2,877
do.	154	Da28	Pa. Tract 66, No. 2	NYSNG Corp. (N676)	11/5/58	1,174
Rockton	155	Eb45	Helen D. S. Gordon 7	NYSNG Corp. (N673)	11/5/58	2,349
do.	156	Fa21	Underhill 3	Devonian Gas & Oil Co.	11/28/58	7,107
Boone Mt.	157	Da19	Pa. Tract 66, No. 3	NYSNG Corp. (N677)	11/24/58	1,608
do.	158	Da33	A. J. Palumbo 3	NYSNG Corp. (N684)	12/6/58	5,305
Rockton	159	Eb31	New Shawmut Mining Co., No. 2	Devonian Gas & Oil Co.	12/17/58	12,105
Boone Mt.	160	Da25	W. & W. Overturf 1	H. S. McKay et al.	2/19/58	5,600
—	161	Dc9	Baker Run Reserve 9	F. C. Deemer	12/19/58	Dry
Boone Mt.	162	Da21	Q. G. Lucore 1	NYSNG Corp. (N689)	1/8/59	14,534
Rockton	163	Eb29	Helen D. S. Gordon 9	NYSNG Corp. (N691)	2/6/59	582
do.	164	Eb33	Helen D. S. Gordon 8	NYSNG Corp. (N683)	2/15/59	2,117
do.	165	Eb30	Pa. Tract 76, No. 6	Manufacturers Light & Heat Co.	2/5/59	720
Boone Mt.	166	Da24	Jos. Overturf 1	S. W. Jack	2/26/59	1,500
—	167	Da23	Pa. Tract 66, No. 4	NYSNG Corp. (N696)	2/27/59	Dry
Rockton	168	Fa22	New Shawmut Mining Co. 1	Devonian Gas & Oil Co.	4/23/59	19,455
do.	169	Fa20	A. J. Palumbo 1	NYSNG Corp. (N694)	3/24/59	9,690

Boone Mt.	170	Ea15	R. J. Anderson 1	James Drilling Co.	3/21/59	7,107
do.	171	Ea25	Lavira Crawford 1	NYSNG Corp. (N697)	3/30/59	15,313
do.	172	Ea20	James Parks 1	Fairman Brothers	3/30/59	7,800
do.	173	Ea14	R. J. Anderson 2	James Drilling Co.	4/2/59	12,600
do.	176	Ea4	A. J. Palumbo et al. 5	NYSNG Corp. (N698)	4/11/59	9,696
Rockton	177	Eb8	A. J. Palumbo 2	NYSNG Corp. (N704)	4/21/59	37,500
Boone Mt.	178	Ca22	A. J. Palumbo 4	NYSNG Corp. (N687)	4/22/59	2,312
Rockton	179	Fb16	New Shawmut Mining Co. 1	Devonian Gas & Oil Co.	6/29/59	18,500
—	180	Ea22	A. V. Crawford 1	Sam Jack	5/15/59	Dry[2]
Boone Mt.	181	Ea7	A. J. Palumbo 7	NYSNG Corp. (N708)	5/13/59	3,373
Rockton	182	Eb28	Hylan Lewis 1	Devonian Gas & Oil Co.	5/2/59	12,000
Boone Mt.	183	Cb1	G. E. Whitmore 1	NYSNG Corp. (N717) & Devonian Gas & Oil Co.	5/15/59	16,800
do.	184	Ea17	John R. Thompson 1	James Drilling Co.	5/14/59	3,456
Rockton	185	Fa10	A. J. Palumbo 3	NYSNG Corp. (N714)	5/20/59	8,660
do.	186	Eb37	Green Glen 1	Lee Minter et al.	5/31/59	45,000
Boone Mt.	187	Ea13	M. W. Bundy 2	James Drilling Co.	6/4/59	8,800
Rockton	188	Fb1	New Shawmut Mining Co. 2	Devonian Gas & Oil Co.	6/8/59	18,000
do.	189	Eb11	Pa. Tract 76, No. 5	Manufacturers Light & Heat Co.	6/17/59	14,700
Boone Mt.	190	Ea26	J. A. Miller 1	H. S. McKay et al.	6/16/59	3,300
Rockton	191	Eb36	Helen D. S. Gordon 11	NYSNG Corp. (N727)	7/8/59	70,000
do.	192	Eb14	Pa. Tract 76, No. 8	Manufacturers Light & Heat Co.	7/9/59	3,890
do.	193	Eb25	Green Glen 2	Lee Minter et al.	7/13/59	12,433
do.	194	Eb27	Hylan Lewis 2	Devonian Gas & Oil Co. et al.	7/12/59	6,625
do.	195	Ea51	A. J. Palumbo 6	NYSNG Corp. (N721)	7/12/59	7,500
do.	196	Ea47	Pa. Tract 86, No. 1	NYSNG Corp. (N723)	7/13/59	13,357
Boone Mt.	197	Da5	Pa. Tract 80, No. 1	NYSNG Corp. (N719)	10/7/59	33

Table 6. *(Continued)*

Pool	Pa. Geol. Survey, Oil & Gas Div., Penfield 15-min. qd. ref. no.	This report, station no.	Well name	Operator	Date completed	Initial production (Mcfd) or status[1]
Boone Mt.	199	Cb7	Frank Sherwood 1	Lee Minter et al.	7/27/59	8,992
Rockton	200	Fb12	Pa. Tract 76, No. 7	Manufacturers Light & Heat Co.	7/17/59	109
Boone Mt.	201	Cb4	Pa. Tract 65, No. 3	NYSNG Corp. (N726)	7/31/59	13,701
Rockton	202	Fa8	Underhill 4	Devonian Gas & Oil Co.	8/8/59	4,000
Boone Mt.	203	Cb5	Weather 1 (Hylan Lewis 1)	do.	8/19/59	10,500
do.	205	Ea5	Anna M. Shutters 1	James Drilling Co.	8/28/59	4,100
Rockton	206	Ea39	A. J. Palumbo 8	NYSNG Corp. (N729)	8/29/59	10,165
do.	207	Eb6	Green Glen 3	Lee Minter et al.	8/27/59	1,500
do.	208	Eb23	Helen D. S. Gordon 12	NYSNG Corp. (N731)	9/4/59	17,500
do.	209	Eb18	Mary E. Gary 1	NYSNG Corp. (N722)	8/24/59	1,233
do.	210	Eb26	Helen D. S. Gordon 10	NYSNG Corp. (N725)	11/12/59	60
Boone Mt.	211	Cb12	H. H. Bundy 1	Fairman Drilling Co.	9/15/59	11,000
do.	212	Cb11	A. Malloney 1	Brunt et al.	9/26/59	10,000
do.	213	Cb6	L. DeSanders 1	NYSNG Corp. (N732)	9/25/59	7,927
Rockton	214	Fa15	A. J. Palumbo 4	NYSNG Corp. (N718)	9/27/59	18,067
Boone Mt.	215	Ea12	M. D. Luchuck 1	James Drilling Co.	9/28/59	12,228
Rockton	216	Fa11	A. J. Palumbo 9	NYSNG Corp. (N734)	10/9/59	15,313
do.	217	Db7	Gordon Gallagher 1	S. W. Jack	10/21/59	42
do.	218	Eb17	DuBois National Bank 1	Harry Brunt et al.	10/27/59	5,930
do.	219	Fa7	George J. Baummer 1	NYSNG Corp. (N737)	10/24/59	3,435
do.	220	Ea40	Pa. Tract 86, No. 2	NYSNG Corp. (N733)	11/2/59	4,332
Boone Mt.	221	Cb8	C. W. Spicher 1	NYSNG Corp. (N736)	11/9/59	7,504
Rockton	222	Db6	Pa. Game Lands Tract 93, No. 1	Fairman Drilling Co.	11/16/59	2,250

do.	223	Ea48	Jas. Thompson 1	James Drilling Co.	11/19/59	5,440
do.	224	Fa4	A. J. Palumbo 10	NYSNG Corp. (N738)	11/14/59	5,731
Boone Mt.	226	Ea11	Patsy Georgino 1	NYSNG Corp. (N739)	11/28/59	15,920
Rockton	227	Db3	Green Glen 4	Lee Minter et al.	12/8/59	2,050
do.	228	Eb16	Mary E. Gary 2	NYSNG Corp. (N740)	12/22/59	2,491
do.	229	Ea50	New Shawmut Mining Co. 3	Devonian Gas & Oil Co.	12/30/59	2,500
do.	230	Fa18	New Shawmut Mining Co. 2	do.	1/9/60	4,125
Boone Mt.	231	Bb30	Green Glen	NYSNG Corp. (N746)	1/15/60	6,676
DuBois	232	Ac9	Green Glen 1-1	S. W. Jack	1/6/60	30,370 Discovery well
Boone Mt.	233	Ea10	Beatrice Sellers 1	Fairman Drilling Co.	1/26/60	4,750
Rockton	234	Fa3	A. J. Palumbo 10	NYSNG Corp. (N743)	2/3/60	2,755
—	236	Fa1	John W. Thomas 1	Harry Brunt et al.	2/6/60	Dry
DuBois	237	Ac18	Green Glen 1-2	S. W. Jack	2/28/60	31,272
do.	238	Ac21	Elwood Minns 1	Fairman Drilling Co.	3/8/60	15,750
do.	239	Ac16	Green Glen 1-3	S. W. Jack	2/28/60	20,000
—	240	Bb37	Deemer-Green Glen 2	Felmont Oil Corp.	2/12/60	Dry
Boone Mt.	241	Bb14	Green Glen 2	NYSNG Corp. (N751)	3/10/60	1,762
—	242	Bb33	Amos Duttry 1	Lee E. Minter	2/12/60	Dry
—	243	Bb29	Alvin Thalgren 1	NYSNG Corp. (N750)	6/14/60	Show
Rockton	244	Ea36	M. D. Luchuck 2	James Drilling Co.	3/22/60	700
DuBois	245	Ac7	Deemer-Green Glen 5	Felmont Oil Corp.	3/18/60	7,000
do.	246	Ac17	Deemer-Green Glen 4	do.	4/2/60	10,000
do.	247	Ac15	Deemer-Green Glen 3	do.	4/27/60	20,000
do.	248	Ac14	Alice Ross Trustee 1	Devonian Gas & Oil Co.	4/16/60	10,000
do.	249	Ac23	Green Glen 1	Lee E. Minter	3/25/60	14,000
do.	250	Ac27	Green Glen 2	do.	4/11/60	25,000
do.	251	Ac25	Deemer-Green Glen 7	Felmont Oil Corp.	5/14/60	20,000
do.	252	Ac20	Deemer-Green Glen 6	do.	5/14/60	17,000
do.	254	Ac30	City of DuBois 1	Kewanee Oil Co.	5/14/60	11,044

Table 6. (*Continued*)

Pool	Pa. Geol. Survey, Oil & Gas Div., Penfield 15-min. qd. ref. no.	This report, station no.	Well name	Operator	Date completed	Initial production (Mcfd) or status[1]
DuBois	255	Ac22	M. E. Trude 1	Fairman Drilling Co.	6/11/60	10,250
do.	256	Ac13	Green Glen 4	S. W. Jack	5/7/60	10,000
do.	257	Ac24	F. M. Hyatt 1	James Drilling Co.	4/14/60	8,000
—	258	Ac3	Green Glen 5	S. W. Jack	5/29/60	Dry
DuBois	259	Ac29	DuBois Country Club No. 3	do.	6/19/60	10,000
do.	260	Ac6	Deemer-Green Glen 8	Felmont Oil Corp.	6/30/60	15,200
do.	262	Ac28	Deemer-Green Glen 10	do.	7/28/60	15,000
Rockton	263	Fa2	C. A. Sherry 1	James Drilling Co.	7/7/60	989
—	264	Bb28	Green Glen 1	Rockton Drilling Co.	8/19/60	Dry
DuBois	265	Ac19	Deemer-Green Glen 11	Felmont Oil Corp.	8/18/60	6,500
Sabula	277	Bb31	Green Glen Corp. 4	NYSNG Corp. (N889) & Devonian Gas & Oil Co.	8/26/63	9,191 Discovery well
—	278	Bb32	H. Dodd 1	Fairman Drilling Co.	1/8/64	Show
Rockton	279	Fa23	Pa. Tract 123, No. 1	Lee E. Minter	1/26/64	1,800
do.	281	Fb5	Pa. Tract 123, No. 2	do.	8/9/64	370
Boone Mt.	Ridgway 1	Ridgway Ef2	A. J. Palumbo 6	NYSNG Corp. (N707)	6/8/59	4,150
do.	Ridgway 204	Ridgway Ff2	A. J. Palumbo 8	NYSNG Corp. (N715)	8/31/59	2,665
—	282	Cc20	Kewanee Oil & Gas 1	Lee E. Minter	2/14/69	Dry

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[1] More complete information on these wells may be found in the following references: Lytle, Bergsten, Cate, and Wagner (1961); Lytle, Bergsten, Cate, Fairall, and others (1961); Lytle and others (1964); Lytle and others (1965); and Kelley and others (1970).

[2] Completed as a shallow gas well.

Table 7. *Shallow Natural Gas Wells in the Sabula and Penfield Quadrangles*

Field	Pa. Geol. Survey, Oil & Gas Div., Penfield 15-min. qd. ref. no.	This report, station no.	Well name	Operator	Date completed	Initial production (Mcfd) or status
Boone Mt.	1	Ca11	—	—	—	—
do.	2	Ca1	United Natural Gas Co., No. 380	—	—	208
do.	3	Ba10	—	—	—	—
do.	4	Ba6	United Natural Gas Co., No. 383	—	—	3,851
do.	5	Ca12	—	—	—	—
do.	6	Ba7	United Natural Gas Co., No. 5607	—	—	1,076
do.	7	Ba5	United Natural Gas Co., No. 369	—	—	74
do.	8	Ba8	—	—	—	—
—	9	Ca3	—	—	—	Show
—	10	Ca16	—	—	—	Show
—	11	Ca6	Logan Bond No. 2	—	—	Dry
Boone Mt.	12	Ca10	—	—	—	—
—	14	Ca19	—	—	—	Show
—	20	Ac8	—	—	—	Dry
—	1-5-1	Aa16	—	—	—	Show
Boone Mt.	—	Ba14	United Natural Gas Co., No. 4751	—	—	—
do.	—	Ba19	United Natural Gas Co., No. 4753	—	—	115
—	—	Ba18	United Natural Gas Co., No. 4755	—	—	—
Boone Mt.	—	Ba24	United Natural Gas Co., No. 4759	—	—	—
do.	—	Ba26	United Natural Gas Co., No. 4760	—	—	—
do.	—	Ba22	United Natural Gas Co., No. 4762	—	—	—
do.	—	Ba28	United Natural Gas Co., No. 4763	—	—	—
do.	—	Ba30	United Natural Gas Co., No. 4764	—	—	—
do.	—	Ba29	United Natural Gas Co., No. 4765	—	—	100
—	—	Ba20	United Natural Gas Co., No. 4766	—	—	—

Table 7. (*Continued*)

Field	Pa. Geol. Survey, Oil & Gas Div., Penfield 15-min. qd. ref. no.	This report, station no.	Well name	Operator	Date completed	Initial production (Mcfd) or status
Boone Mt.	—	Ba27	United Natural Gas Co., No. 4769	—	—	44
—	—	Ba16	United Natural Gas Co., No. 4770	—	—	—
—	—	Ba23	United Natural Gas Co., No. 4809	—	—	—
Boone Mt.	—	Ba25	United Natural Gas Co., No. 4938	—	—	268
do.	—	Bb2	United Natural Gas Co., No. 4967	—	—	7,693
do.	—	Bb1	United Natural Gas Co., No. 4968	—	—	22
do.	—	Bb4	United Natural Gas Co., No. 4970	—	—	117
—	—	Bb3	United Natural Gas Co., No. 5587	—	—	Dry
—	—	Aa15	—	—	—	—
—	—	Ba17	—	—	—	—
—	13	Dc16	Whitney Realty No. 6	Lomega Exploration Ltd.	1957	Dry
—	15	Eb56	—	—	—	—
Hollywood Pool	17	Ea43	Mario Riccadonna 2	Naoma Oil & Gas Co.	10/25/59	15
do.	18	Ea3	Comm. of Pa. Parcel #3, No. 1-A	Devonian Gas & Oil Co.	9/12/59	30,000
—	22	Ea2	—	—	—	Show
Hollywood Pool	26	Ea27	Earl Young 1	James Drilling Co.	4/13/59	21,000
—	27	Ea45	Mario Riccadonna 1	Naoma Oil & Gas Co.	7/18/57	Show
—	—	Ba12	—	—	—	—
Boone Mt.	11	Ca5	Logan L. Bond 1	NYSNG Corp.	3/25/57	539[1]

[1] Drilled as deep well, but plugged back for shallow gas.

The Onondaga chert is a light-gray to brownish-gray to dark-gray, slightly silty, noncalcareous bedded chert with some dark siliceous shales in the lower part. Generally the first show of gas is not encountered until the Ridgeley Sandstone has been penetrated. The chert yields a significant amount of gas only after both units have been fractured (Lytle and others, 1959, p. 8). In addition, the chert is not a potential reservoir unless the Ridgeley Sandstone is an effective reservoir.

The Ridgeley Sandstone is a light-gray, medium- to coarse-grained, quartzose sandstone; it contains siliceous cement which is partly replaced by calcite cement toward the base.

Upper Devonian Sands (Shallow Well Production)

The shallow producing horizons in the report area are all below the "pink rock" of drillers' terminology. Some of the drill records list the Clarion, Deemer, Elk, and Tioga sands as the producing sands. Allowing for errors in correlation, it is highly probable that several horizons from the Speechley sand down to the Kane and Haskill sands are pay zones.

These Upper Devonian sands are commonly light-brown, very fine grained, slightly calcareous, argillaceous sandstones. Hydrofracturing is commonly necessary in the completion of a well.

The production records and other pertinent data on the wells in the Sabula-Penfield area may be found in Lytle, Bergsten, Cate, and others (1961), Lytle, Bergsten, Cate, and Wagner (1961), Lytle and others (1964), Lytle and others (1965), and Kelley and others (1969).

WATER

SURFACE WATER

The topography and surface drainage system in the Sabula-Penfield area are discussed in the section on physiography in this report.

There is an abundance of surface water in the report area. Several of the major streams have been dammed for recreational purposes or for municipal water supplies. Unfortunately, it appears that some of the surface water is unpotable because of the drainage of acid mine water from coal mines. Coal and its associated rocks often contain compounds of sulfur which, when exposed to air and water, form sulfuric acid. Because of this, the runoff from strip mines and much of the water pumped from deep mines are acidic and contain high concentrations of dissolved minerals.

The quality of the water in Bennett Branch of Sinnemahoning Creek was checked near Driftwood, approximately 25 miles downstream from the report area. The water in Anderson Creek was also sampled near

Curwensville, which is about 11 miles to the south (McCarren, 1964). These analyses are listed in Table 8.

It is readily apparent that the large amount of sulfate and the low pH of the water in Bennett Branch is due to the many deep mines along the stream, especially around Penfield, Hollywood, and Tyler. These mines have all contributed acid mine water to Bennett Branch. A research water treatment plant was installed near Hollywood (Fa31). This plant was designed and operated by the Mineral Preparation Department of the Pennsylvania State University. The plant site was originally selected to treat water from four different sources. These sources include large variations in type and level of contaminants. Because of this, the plant was designed to treat water with pH ranging from 2.60-4.30, acidity (ppm (parts per million) $CaCO_3$) varying from 39-8100, and wide variations (in ppm) of iron, aluminum, and sulfate. The treated water was to have a pH ranging from 6 to 9, no titratable acidity, and an iron content less than 7 milligrams per liter. The plant has been closed since June of 1972 and future plans for the installation are uncertain.

The water in Little Toby Creek and Sandy Lick Creek has not been analyzed, although the water in their main streams (Clarion River and Redbank Creek, respectively) has been checked several miles downstream.

GROUND WATER

Supplies of ground water in the area appear adequate. Lohman (1938, p. 197-198) gives information on six wells drilled in the Sabula-Penfield area. These wells are numbered 19, 20, 21, 22, 23, and 25 in that report. The following data are given for these wells:

> Well 19, located near Sabula (Bc4), was drilled by the Pennsylvania Railroad to a depth of 75 feet. It bottomed in black shale of Conemaugh age and produced about 20 gpm (gallons per minute) for domestic purposes.
>
> Well 20, located near Sabula (Cc3), was owned by Dr. Beal and drilled to a depth of 120 feet, bottoming in a Conemaugh sandstone. This well produced about 10 gpm for domestic use.
>
> Well 21, owned by Shawmut Mining Company and located at Hollywood (Ea9), was drilled to a depth of 120 feet. This well produced about 5 gpm from Allegheny shale and was used for domestic purposes. The company reported 7 wells in a row here, all similar and all cased through a considerable thickness of sand and gravel.
>
> Well 22, located at Tyler (Fa5) and owned by the Buffalo and Susquehanna Coal and Coke Company, was drilled to a depth of 40 feet. The production from Allegheny shale was not listed, but the water was reported to be acid and to contain excess iron.
>
> Well 23 (Bc8, located 0.9 mile southeast of Narrows Creek), was drilled to a depth of 580 feet. The well was flowing with a static head of +11 feet. The major flow was from 180 feet in the hole.
>
> Well 25, located 1.2 miles north of Homecamp along the southern border of the report area (Cc15), was owned by Fred Weber. It was drilled to a depth of 78 feet in Conemaugh shale. It produced 1 to 3 gpm for domestic purposes.

Table 8. *Chemical Analyses of Streams in the West Branch Susquehanna River Basin near Clearfield, Pennsylvania*

(After McCarren, 1964, Table 2; results in parts per million)

Date of collection	Mean discharge (cfs)	Temperature (°F)	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Hardness as $CaCO_3$: Calcium, magnesium	Hardness as $CaCO_3$: Noncarbonate	Total acidity as H_2SO_4	pH
Bennett Branch Sinnemahoning Creek near Driftwood																			
Oct. 10, 1957	14.1	58	—	—	—	—	—	—	—	—	0	228	22	—	0.2	116	116	3.3	3.35
Anderson Creek at Curwensville																			
Sept. 11, 1945[1]	—	70	4.6	2.1	0.24	.80	88	3.1	—	—	0	53	1.0	—	0.6	56	56	25	3.85
Oct. 7, 1957	8.0	56	—	—	.38	.88	—	—	—	—	0	81	3.0	—	.2	38	38	39	3.60
Apr. 26, 1960	—	—	—	—	—	—	—	—	—	—	—	57	—	—	—	—	—	20	3.90

[1] Calcium and magnesium not determined separately.

In addition to the above wells, several water wells have been drilled more recently in the Sabula-Penfield area. Well Cf16 (Ec8), owned by Edward Bell and located along Pa. Route 153 about 4 miles east of Penfield, produced about 20 gpm. This well bottomed in a Pottsville sandstone. Well Cf33 (Cb10), owned by Don Mathers and located along Pa. Route 255 between Sabula and Penfield, was drilled to a depth of 215 feet. It produced about 20 gpm from a Conemaugh sandstone. In October of 1969, an emergency water well was drilled along Whetstone Branch at Aa4 by the Brockway Borough Water Authority. The well was located at what is believed to be the intersection of two very strong fracture traces. It was spudded in the lower part of the Pocono Formation on the northwestern flank of the Boone Mountain anticline. The 8-inch-diameter well was drilled to a depth of 120 feet and was flowing at about 285 gpm with an estimated static head of +40 feet. The major flow started at 86 feet. Pumping at 30 feet to 365 gpm lowered the water level 18 feet 4 inches below the top of the hole. Further drilling was done by the Borough in 1970 near the lower Brockway Reservoir (Ba1). This second well penetrated 168 feet of the Pocono with a minimum 12-inch-diameter hole. This well was also flowing at about 40 gpm. Pumping at 121 feet yielded 240 gpm. The main aquifer was at 151 feet.

Sandstone generally has good porosity and effective permeability, and is considered to be the best aquifer. Although shale has porosity, the pore spaces are so small that water does not readily move through it. For this reason, shale usually does not yield as much water as sandstone. However, if the shale is strongly jointed, good yields are not uncommon. Fracture porosity apparently dominates any initial porosity in the sandstones and is a major factor in evaluating aquifers. A detailed analysis of fracture traces should accompany any well location study.

Wells bottoming in coal beds do not usually yield large amounts of ground water. The water may be good, but if the coal has been mined, the water may be highly acidic.

ENGINEERING GEOLOGY

Plate 10 is a generalized evaluation of the engineering characteristics of the various geological units that are exposed in the Sabula-Penfield area. Each unit is classified in one of five categories, the characteristics of which are described on the plate. A brief evaluation of the economic potential of each category for construction materials is included, along with a short summary of ground-water availability.

This plate is designed to supplement the geologic map of this report (Plate 1) and is keyed to the geologic units shown on it.

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GLOSSARY

This glossary is intended primarily for nontechnical readers, thus the definitions are often somewhat simplified.

Alluvium. Sand, gravel, or other similar particle material deposited by running water.

Anticline. An upfold or arch of stratified rock in which the beds dip in opposite directions from the crest.

Aquifer. A formation or rock unit that is water bearing.

Attritus. Plant debris that constitutes the microfragmental matrix in coal. Its luster is not as brilliant as that of vitrain nor as dull as that of fusain.

Basement. A widespread complex of igneous and metamorphic rocks underlying the sedimentary rock sequence.

Bedding. The physical layering within sedimentary rocks dividing rocks of similar or different rock types.

Bioturbation. The disruption of bedding in unconsolidated sediments by organisms.

Blossom (coal). Decomposed outcrop of a coal bed.

Bone (bony coal). A coal high in inorganic material, usually clay and fine silt. Bone covers the range between clean coal and coaly shale.

Cannel shale. A black shale consisting of silt and clay that was deposited with swamp organic ooze.

Clastic. Composed of material mechanically eroded from preexisting rocks. Refers primarily to clay, silt, sand, gravel, etc.

Compaction. The decrease in the volume of sediments resulting from compression. It is usually caused by the weight of overlying sediments.

Contour, structural. An imaginary line connecting points of equal elevation on a selected bedding surface.

Contour, topographic. An imaginary line connecting points of equal elevation on the surface of the earth.

Crossbedding. The arrangement within a rock unit of strata or bedding at an angle to the main planes of stratification or the main bedding surface of that rock unit.

Décollement. The independent folding and faulting of sedimentary beds resulting from the sliding of those rocks along a detached zone above underlying rocks. Also, the detachment surface upon which sliding takes place.

Delta. An accumulation of sediments formed by deposition of river-borne materials at the edge of a large water body.

Delta front. A complex of related depositional environments in advance of the delta plain, including distal bars, distributary-mouth bars, distributary channels, etc.

Dendritic drainage. A drainage system which is characterized by an irregular branching pattern.

Detrital. Composed of material mechanically eroded from preexisting rocks. Refers primarily to clay, silt, sand, gravel, etc.

Diagenesis. The changes that occur in sediments after deposition but prior to consolidation into rock. These changes may be caused by compaction, bacterial action, organisms, permeating water, or chemical reactions.

Diastem. A minor time interval of nondeposition or hiatus within sedimentary rocks.

Dip. The angle at which a layer of rock is inclined to horizontal.

Disconformity. A major depositional and erosional interruption within a sequence of sedimentary rocks, the rocks on either side of which are bedded essentially parallel.

Epicontinental. Located on a continental land mass, either past or present.

Epineritic. The marine environment that extends from low tide to a depth of water not exceeding 120 feet.

Facies. The sum of all the characteristics of a rock unit, including composition, color, bedding, fossil suite, and any other characteristic which can be measured or described. When one or more aspects of a rock unit change vertically or laterally (such as grading from shale to sandstone), this variation is spoken of as *facies change.*

Fault. A fracture or fracture zone within the rocks along which there has been some movement of the two sides relative to one another. This should be distinguished from a coal miner's fault, which is a term used to describe any disruption of a coal seam.

Fissility. The property of a rock characterized by splitting along closely spaced parallel planes.

Flaser bedding. Lenticular bedding, characteristic of tidal flats.

Flint clay. See Hard clay.

Flora (fossil). An assemblage of fossilized plants.

Fluvial. Related to or produced by streams or rivers.

Fold. A bend or flexure produced in rock strata by forces operating after deposition of the rock.

Fold height. Maximum difference in elevation of a specific datum surface between axes of an anticline and a flanking syncline (see *Structural relief*).

Footwall. The rock mass beneath a fault plane.

Formation. A body of relatively homogeneous rock, usually tabular, and mappable at the surface of the earth. A formation may be bounded by key beds (q.v.).

Friable. Poorly cemented and easily crumbled.

Fusain. An ingredient of coal that has a fibrous structure like charcoal.

Geosyncline. A very large land area of regional extent which subsides for a long period of time and in which sedimentary and volcanic rocks are accumulating.

Group. A rock-stratigraphic unit consisting of two or more formations.

Hanging wall. The rock mass above a fault plane.

Hard clay. A hard, brittle variety of clay found beneath some coal seams which has a sharp conchoidal fracture. It has a strong superficial resemblance to limestone. Pure hard clay is composed mostly or entirely of very finely crystalline kaolinite (q.v.), but may contain various impurities such as iron oxide, silica, diaspore, boehmite, etc. Hard clay also grades into the more usual soft clay (q.v.).

Igneous rocks. Rocks formed by solidification from a molten or partially molten state.

Immature texture. Said of sandstones that have more than 5 percent clay matrix, are poorly sorted, and have angular grains.

Iridescence. A play of colors (producing rainbow effects) on the surface or interior of a mineral.

Joint. A fracture in a rock along which no movement has taken place.

Kaolinite. A clay mineral with the chemical composition $Al_2Si_2O_5\ (OH)_4$.

Key bed. A bed that is distinctive enough to make it easily identifiable over a wide area. Key beds such as coals are often used as boundaries for a formation (q.v.).

Laminite. Sedimentary rocks in which the layers or laminae are less than 1 centimeter thick.

Lithology. The physical characteristics of a rock, usually as determined by examination with the naked eye or with the aid of a low-power magnifier.

Lithosome. A rock-stratigraphic body that has characteristic composition, texture, and sedimentary structures, and is mutually intertongued with other differing bodies.

Master joint. A large and persistent joint passing through all rock masses in an area and of a magnitude considerably greater than normal surface joints. A master joint may be the extension of fracture beyond displacement of a major fault (q.v.).

Member. A subdivision of a formation (q.v.), based on physical, chemical, or biological properties.

Muscovite. A mica mineral occurring as thin transparent sheets or flakes, having the chemical composition $KAl_3Si_3O_{10}(OH)_2$.

Normal fault. A fault that has the hanging wall (q.v.) moved downward relative to the footwall (q.v.).

Orogeny. The process of mountain building, especially by folding and faulting of the rocks.

Paleobotany. The study of fossil plants.

Paleoslope. The regional slope of an ancient land surface.

Paleotopography. The relief and contour of the land at a specific time in the geologic past, usually defined by a fossil erosion surface or unconformity (q.v.).

Periglacial. Referring to the region adjacent to the margin of a past or present glacier or ice sheet.

Permeability. Ability of a rock to allow fluids to pass through.

Physiography. The study of the surface features of the earth, including their form, nature, origin, development, and the changes they are undergoing.

Point bar. An arcuate sand and gravel deposit that accumulates on the inside of a river meander bend.

Porosity. The volume percentage of pore space or interstices in a rock with reference to its total volume.

Prodelta. Offshore or seaward from a river delta; area where first fine sediments originating from the land are introduced by an advancing delta.

Progradation. A seaward advance of the shoreline resulting from nearshore deposition of sediments brought to the sea by rivers. *Prograded sequence* and *prograded rocks* are the rocks consolidated from the sediments deposited in a prograding situation, and usually become coarser grained upward.

Regression. The gradual contraction of a shallow sea resulting in the emergence of land when sea level falls or the land rises, or when progradation (q.v.) occurs.

Relief (structural). The difference in elevation between high and low points of a selected stratigraphic datum horizon, reflecting the amount of folding and/or faulting.

Relief (topographic). Difference in elevation of high and low points of the surface of the earth within a specified area.

Reverse fault. A fault that has the hanging wall (q.v.) moved upward relative to the footwall (q.v.).

Rider coal. A thin seam of coal overlying a thicker one.

Rootlets. Thin, flat, fossil roots (usually 1/8 to 1/4 inch wide), commonly found laced throughout clays beneath coal seams. Occasionally some rootlets are found attached to larger, identifiable roots of coal-swamp plants.

Sediment. Solid material, of either physical, chemical, or organic origin, which is being, or has at one time been, transported from the site of its origin by moving air, water, or ice.

Sedimentary rocks. Rock formed from an accumulation of sediments, which may be composed of rock fragments, plant or animal remains, chemical action products, or evaporation products.

Sedimentology. The study of all matters affecting sediments from the initial formation of sediments from a parent rock through the transportation of sediment from the site of its formation to the site of its deposition.

Siderite. A mineral composed of iron carbonate ($FeCO_3$). The siderite nodules and bands discussed in this report are a mixture of siderite and clay.

Slickensides. The polished and often striated surfaces that are caused by faulting or differential movement in the rocks in which they are found.

Soft clay. A bed of clay occurring below a coal seam. Also called underclay or plastic clay.

Stratigraphy. The study of layered sedimentary rocks.

Stratum (plural: strata). A single sedimentary bed or layer.

Stream capture. The diversion of the upper part of one stream by the headward growth of another stream. Also called *stream piracy.*

Strike. The compass direction of a horizontal line included in the surface of an inclined stratum or other planar feature. The direction of strike is perpendicular to the direction of dip.

Structural geology. The study of the structure or geometry of the rocks of the earth as produced by movements within the earth, and also the nature and cause of these movements.

Structural relief. See Relief, structural.

Structural contour. See Contour, structural.

Subaerial. Formed or occurring on the land surface.

Submature texture. Said of sandstones that have less than 5 percent clay matrix, are poorly sorted, and have angular grains.

Subphyllarenite. A variety of sandstone defined by Folk (1968) that has a framework of quartz ranging from 75 to 95 percent and a rock fragment/feldspar ratio greater than 2:2; rock fragments are dominantly metamorphic.

Subsidence. The sinking of a large part of the earth's surface.

Syncline. A downfold or depression of stratified rock that dips inward toward the axis of the fold.

Tectonic. Refers to rock structure resulting from deformation of the earth's crust.

Terrigenous. Deposited in or on the continental surface.

Topographic contour. See Contour, topographic.

Topographic relief. See Relief, topographic.

Transgression. The gradual expansion of a shallow sea resulting in the submergence of land when sea level rises or the land falls.

Type section. An accurately located section of measured and fully described strata representing the original concept of a certain formation or member (q.v.).

Unconformity. A surface of erosion representing a period of nondeposition separating younger and older rocks.

Underclay. A layer of clay occurring below a coal seam. Also called plastic clay or soft clay.

Vitrain. The portion of coal that occurs in shiny black bands and has a brilliant gloss.

Watershed. The area within a drainage basin from which all surface water drains to a given point on a stream.

APPENDIX 8

FIRING TESTS AND PHYSICAL DATA ON CLAYS AND CLAY SHALES

Analysis of Clay Sample from Station Ec5

	Dried 225°F	Calcined
Ignition loss	7.24%	
Silica	60.52	65.24%
Alumina	22.87	24.66
Iron oxide	2.60	2.80
Titania	2.39	2.57
Lime	0.20	0.22
Magnesia	0.55	0.59
Alkalies	3.50	3.77
TOTAL	99.87%	99.85%

PCE on a sample of green clay - cone 20-23 (2885°F)

SAMPLE NO. 64-3-1 (from O'Neill and others, 1965, p. 186-187)

Description: Medium- to medium-light-gray underclay of the Lower Kittanning coal is exposed in the quarry. The clay is eight feet thick. Its top occurs about 50 feet below the surface of the ridge.

Chemical Analysis:

SiO_2	60.80%	Na_2O	.25%
Al_2O_3	24.55	TiO_2	1.34
Fe_2O_3	1.71	L.O.I.	8.00
FeO	.46	S	.29
CaO	.12	CO_2	5.95
MgO	.45	Comb. H_2O	.90
K_2O	2.30	H_2O @ 120°C	.86

Mineralogy: X-ray:		Accuracy (±)
Quartz	41%	10
Mica	39	10
Kaolinite	10	8
C-V-Mo	1	3
Feldspar	0	3

Other tests:

pH: 7.3
Workability: fairly plastic and smooth
Water of plasticity %: 31.0
% Drying shrinkage: 4.5
Dry strength: average

Slow-firing tests:

Temp. °F	Color	Hardness	%Shk.	%Abs.	Approx. Sp. Gr.
1800	Very lt. buff	Soft, crumbly	5.5	15.9	2.58
1900	Very lt. buff	Soft, crumbly	5.5	16.3	2.62
2000	Light buff	Hard	8.0	13.4	2.59
2100	Light tan	Steel hard	9.5	9.7	2.58
2200	Tan	Steel hard	9.5	6.4	2.53
2300	Tan gray	Steel hard	13.0	1.4	2.38

Bloating test: negative

Pyrometric cone equivalent: 23

Cone color: gray

Potential uses: Brick, tile; possibly low-duty refractory products such as ladle brick.

SAMPLE NO. 74A-13

Interval in core: 55.4 - 59.2 ft

Unit: Claystone below Cambridge-Pine Creek marine zone

Raw data:

pH: 8.0
Workability: gritty
Plasticity: good
Water of plasticity %: 17.9
% drying shrinkage, plastic basis: 6.0
Dry strength: p.s.i. 365
Drying properties: good

Slow-firing tests: L.O.I. 10.4%

Heating rate: 525°F/hr to 1800°F, then 125°F/hr

Temp. °F	Color	Moh's hardness	Total shrinkage percent	Firing shrinkage percent	Absorption percent	Apparent sp. gr.	Bulk density
1900	Buff	7+	10.0	4.0	6.8	2.47	2.11
2000	Med. br.	7+	12.0	6.0	2.4	2.42	2.28
2100	Med. br.	7+	13.0	7.0	1.8	2.44	2.33
2200	Gray grn.	7+	6.0	0.0	1.9	1.93	1.86

Quick-firing test: E. C. 139 micromhos/cm

Retention time, minutes: 15		Temperature °F 1900	2000	2100	2200
Particle size through 525 on 4	Weight lb/cu ft	112.9	102.3	103.0	100.5
	Absorption percent	6.6	7.1	6.5	6.7

Other tests and comments: Extrudes excellent (gritty). $CaCO_3$ positive. 2200°F slight cracking. Slight scumming noted at 2000° and 2100°F. Good color range between 2000° and 2100°F.

Potential uses: Probable use as sole component in brick and tile. Probable use in sewer pipe. Possible use in domestic artware and earthenware industries.

SAMPLE NO. 74A-14

Interval in core: 241.75 - 251.0 ft

Unit: Claystone/clay shale below the Upper Freeport coal

Raw data:

pH: 8.3
Workability: Gritty
Plasticity: Good
Water of plasticity %: 9.0
% drying shrinkage, plastic basis: 5.0
Dry strength: p.s.i. 151
Drying properties: Good

Slow-firing tests: L.O.I. 10.1%

Heating rate: 525°F/hr to 1800°F, then 125°F/hr

Temp. °F	Color	Moh's hardness	Total shrinkage percent	Firing shrinkage percent	Absorption percent	Apparent sp. gr.	Bulk density
1900	Lt. or. br.	6	5.5	0.5	11.2	2.57	2.00
2000	Or. br.	7	8.0	3.0	7.0	2.21	1.91
2100	Med. r. br.	7	8.0	3.0	5.9	2.60	2.25
2200	Dk. gry. br.	7+	10.0	5.0	1.7	2.25	2.16

Quick-firing test: E. C. 149 micromhos/cm

Retention time, minutes: 15		Temperature °F			
		1900	2000	2100	2200
Particle size through 525 on 4	Weight lb/cu ft	122.3	119.8	111.6	107.3
	Absorption percent	8.4	9.8	8.3	11.0

Other tests and comments: Extrudes excellent (gritty). $CaCO_3$ slightly positive. Fair color range between 2000° and 2100°F.

Potential uses: Probable use as sole component in most structural clay products. Probable use in sewer pipe.

SAMPLE NO.   74A-15

Interval in core: 289.6 - 292.5 ft

Unit: Silt/clay shale below the Lower Freeport coal

Raw data:

pH: 7.5
Workability: Gritty
Plasticity: Good
Water of plasticity %: 10.8
% drying shrinkage, plastic basis: 4.0
Dry strength: p.s.i. 161
Drying properties: Good

Slow-firing tests: L.O.I. 6.1%

Heating rate: 525°F/hr to 1800°F, then 125°F/hr

Temp. °F	Color	Moh's hardness	Total shrinkage percent	Firing shrinkage percent	Absorption percent	Apparent sp. gr.	Bulk density
1900 A	Lt. or. br.	3	7.0	3.0	29.1	2.55	1.46
2000 B	R. br.	5.5	12.0	8.0	20.0	2.45	1.64
2100 C	R. br.	7	12.5	8.5	14.1	2.44	1.81
2200 D	Dk. gry. br.	7+	12.0	8.0	10.8	1.90	1.57

Quick-firing test: E. C. 240 micromhos/cm

Retention time, minutes: 15		Temperature °F			
		1900	2000	2100	2200
Particle size through 525 on 4	Weight lb/cu ft	108.6	106.1	98.6	98.0
	Absorption percent	7.4	8.2	7.4	5.2

Other tests and comments: Extrudes good (gritty). $CaCO_3$ negative. 2200°F bloating indicated. Pitting indicated on samples A, B, C.

Potential uses: None in structural clay products. Possible extra-light aggregate.

SAMPLE NO. 74A-16

Interval in core: 396.8 - 401.5 ft

Unit: Claystone below the Middle Kittanning coal

Raw data:

pH: 7.2
Workability: Gritty
Plasticity: Good
Water of plasticity %: 2.9
% drying shrinkage, plastic basis: 4.0
Drying strength: p.s.i. 89
Drying properties: Good

Slow-firing tests: L.O.I. 6.6%

Heating rate: 525°F/hr to 1800°F, then 125°F/hr

Temp. °F	Color	Moh's hardness	Total shrinkage percent	Firing shrinkage percent	Absorption percent	Apparent sp. gr.	Bulk density
1900 A	Med. tan	3	6.0	2.0	17.6	2.53	1.75
2000 B	Lt. br.	6	8.2	4.2	12.8	2.50	1.89
2100 C	Lt. r. br.	7+	9.0	5.0	9.3	2.54	2.05
2200 D	Dk. br.	7+	13.0	9.0	6.1	2.47	2.14

Quick-firing test: E. C. 168 micromhos/cm

Retention time, minutes: 15		Temperature °F 1900	2000	2100	2200
Particle size through 525 on 4	Weight lb/cu ft	140.4	131.0	116.7	115.5
	Absorption percent	6.6	6.3	6.4	4.3

Other tests and comments: Extrudes fair (gritty). $CaCO_3$ negative. Slight scumming indicated at 2000°F and 2100°F. Suggest the addition of a more plastic material to improve dry strength.

Potential uses: Probable use in most structural clay products including sewer pipe. Probable use in the domestic artware and earthenware industries.

SAMPLE NO. 74A-17

Interval in core: 463.05 - 485.8 ft

Unit: Lower Kittanning underclay

Raw data:

pH: 7.2
Workability: Gritty
Plasticity: Poor
Water of plasticity %: 7.3
% drying shrinkage, plastic basis: 3.5
Dry strength: p.s.i. 145
Drying properties: Good

Slow-firing tests: L.O.I. 12.6%

Heating rate: 525°F/hr to 1800°F, then 125°F/hr

Temp. °F	Color	Moh's hardness	Total shrinkage percent	Firing shrinkage percent	Absorption percent	Apparent sp. gr.	Bulk density
1900 A	Lt. pink	3	5.0	1.5	16.1	2.70	1.88
2000 B	Lt. pink	5	5.5	2.0	14.5	2.60	1.99
2100 C	Lt. pink	7	5.5	2.0	13.6	2.75	2.00
2200 D	Pink gray	7	7.0	3.5	12.1	2.62	1.98

Quick-firing test: E. C. 144 micromhos/cm

Retention time, minutes: 15		Temperature °F			
		1900	2000	2100	2200
Particle size through 525 on 4	Weight lb/cu ft	156.0	152.9	144.8	146.0
	Absorption percent	6.8	7.5	6.9	7.9

Other tests and comments: Extrudes fair (gritty). $CaCO_3$ negative.

Potential uses: Possible use as a nonplastic filler in most structural clay products except sewer pipe.

SAMPLE NO. 74A-18

Interval in core: 485.8 - 506.4 ft

Unit: Lower Kittanning underclay

Raw data:

pH: 8.1
Workability: Gritty
Plasticity: Poor
Water of plasticity %: 15.5
% drying shrinkage, plastic basis: 4.0
Dry strength: p.s.i. 131
Drying properties: Good

Slow-firing tests: L.O.I. 8.5%

Heating rate: 525°F/hr to 1800°F, then 125°F/hr

Temp. °F	Color	Moh's hardness	Total shrinkage percent	Firing shrinkage percent	Absorption percent	Apparent sp. gr.	Bulk density
1900 A	Cream	3	4.0	0.0	13.2	4.32	2.74
2000 B	Lt. tan	5	5.0	1.0	10.2	2.50	1.98
2100 C	Gray cream	6	2.0	-2.0	13.5	2.39	1.80
2400 D	Gray grn.	7+	8.0	4.0	3.5	2.28	2.11
2600 E	Dk. gry. grn.	7+	0.0	0.0	11.0	2.00	1.63

Quick-firing test: E. C. 80 micromhos/cm

Retention time, minutes: 15		Temperature °F			
		1900	2000	2100	2200
Particle size through 525 on 4	Weight lb/cu ft	142.3	127.3	114.8	127.3
	Absorption percent	9.8	9.8	8.6	7.6

Other tests and comments: Extrudes good (gritty). $CaCO_3$ negative. 2100°F slight cracking. Bloating, warping, and slight cracking with 2600°F tile.

Potential uses: Possible use as a nonplastic filler in most structural clay products except sewer pipe.

SAMPLE NO. 74A-19

Interval in core: 542.2 - 549.3 ft

Unit: Clay below the Clarion no. 2 coal

Raw data:

pH: 7.9
Workability: Gritty
Plasticity: Poor
Water of plasticity %: 18.0
% drying shrinkage, plastic basis: 3.9
Dry strength: p.s.i. 136
Drying properties: Good

Slow-firing tests: L.O.I. 6.7%

Heating rate: 525°F/hr to 1800°F, then 125°F/hr

Temp. °F	Color	Moh's hardness	Total shrinkage percent	Firing shrinkage percent	Absorption percent	Apparent sp. gr.	Bulk density
1900	Cream	3	3.9	0.0	12.7	2.49	1.89
2000	Yel. cream	6	5.0	1.1	11.4	2.47	1.93
2100	Yel. cream	6	6.0	2.1	13.0	2.27	1.75
2400	Lt. yel. grn.	7+	8.0	4.1	4.0	2.37	2.16
2600	Lt. yel. grn.	7+	5.5	1.3	7.7	2.12	1.82

Quick-firing test: E. C. 64 micromhos/cm

Retention time, minutes: 15		Temperature °F			
		1900	2000	2100	2200
Particle size through 525 on 4	Weight lb/cu ft	129.8	132.3	129.8	127.3
	Absorption percent	7.9	9.9	6.9	7.0

Other tests and comments: Extrudes fair (gritty). $CaCO_3$ slightly positive. 2100°F slight cracking. 2600°F slight cracking.

Pyrometric cone equivalent: 23

Potential uses: Possible use as a component in low-duty refractories. Possible use in the domestic stoneware industry.

SAMPLE NO. 74A-20

Interval in core: 551.6 - 554.3 ft

Unit: Clay below the Clarion no. 2 coal

Raw data:

pH: 7.7
Workability: Gritty
Plasticity: Poor
Water of plasticity %: 14.6
% drying shrinkage, plastic basis: 4.0
Dry strength: p.s.i. 105
Drying properties: Good

Slow-firing tests: L.O.I. 7.0%

Heating rate: 525°F/hr to 1800°F, then 125°F/hr

Temp. °F	Color	Moh's hardness	Total shrinkage percent	Firing shrinkage percent	Absorption percent	Apparent sp. gr.	Bulk density
1900	Lt. gry. br. tan	3	3.0	1.0	13.6	2.58	1.90
2000	Yel. cream	6	3.5	0.5	11.8	2.48	1.92
2100	Yel. cream	6	2.5	1.5	13.3	2.34	1.81
2400	Lt. yel. grn.	7+	6.5	1.0	4.6	2.45	2.20
2600	Lt. yel. grn.	7+	5.0	1.0	7.8	2.43	1.83

Quick-firing test: E. C. 56 michromhos/cm

Retention time, minutes: 15		Temperature °F			
		1900	2000	2100	2200
Particle size through 525 on 4	Weight lb/cu ft	168.6	146.6	146.6	140.4
	Absorption percent	7.4	7.9	6.9	8.3

Other tests and comments: Extrudes fair (gritty). $CaCO_3$ slightly positive. 2100°F slight cracking.

Pyrometric cone equivalent: 20

Potential uses: Possible use as a component in low-duty refractories. Possible use in the domestic stoneware industry.

SAMPLE NO. 74A-21 (Station Ec5)

20-ft channel sample

Unit: Lower Kittanning underclay

Raw data:

pH: 6.0
Workability: Gritty
Plasticity: Fair
Water of plasticity %: 15.9
% drying shrinkage, plastic basis: 4.1
Dry strength: p.s.i. 84
Drying properties: Good

Slow-firing tests: L.O.I. 8.4%

Heating rate: 525°F/hr to 1800°F, then 125°F/hr

Temp. °F	Color	Moh's hardness	Total shrinkage percent	Firing shrinkage percent	Absorption percent	Apparent sp. gr.	Bulk density
1900 A	Lt. pink	4	4.0	0.1	13.2	2.56	1.91
2000 B	Yel. white	6	5.0	1.0	10.4	2.45	1.95
2100 C	Lt. yel. white	6	5.0	0.9	11.9	2.49	1.91
2400 D	Lt. yel. grn.	7+	11.5	7.5	3.5	2.45	2.25
2600 E	Lt. yel. grn.	7+	6.0	2.0	8.2	2.22	1.87

Quick-firing test: E. C. 124 micromhos/cm

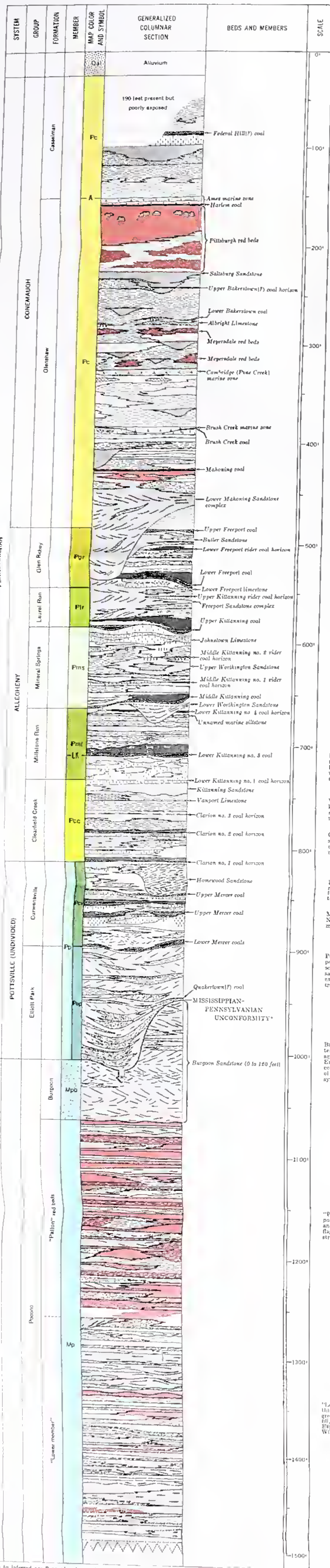
Retention time, minutes: 15		Temperature °F			
		1900	2000	2100	2200
Particle size through 525 on 4	Weight lb/cu ft	165.4	165.4	165.4	162.2
	Absorption percent	6.9	6.9	5.9	6.5

Other tests and comments: Extrudes fair (gritty). $CaCO_3$ negative.

Pyrometric cone equivalent: 23

Potential uses: Possible use as a component in low-duty refractories. Possible use in the domestic stoneware industry.

TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, *State Geologist*



INDUSTRIAL ROCKS AND MINERALS AND COAL

Alluvium: local source of medium-grade aggregate; sand and gravel production will require washing considerable clay; flat and elongated pebbles common, shale clasts common. Extensive deposits in floodplains of Sandy Lick Creek, Anderson Creek, Bennett Branch, and Little Toby Creek.

Federal Hill(?) coal: possibly an important coal seam, not exploited to any large degree at present, misidentified by miners as Upper Freeport, subsurface exploration and testing recommended. Accessory underclay a potential source of material for structural clay products.

Clay shale sequence above Ames marine zone: some potential as minor source of material for structural clay products.

Harlem coal: thin but persistent coal; no economic potential at present.

Pittsburgh red beds: important potential source of varying materials for production of structural clay products; reddish-gray to olive-green colors some large carbonate concretions near top. Exposed at several localities around Sabula.

Albright Limestone: occurrence noted in several drilling records; minor potential source of agricultural lime or water-neutralizing agent in coal mining operations.

Meyersdale red beds: potential source of red clay shale for structural clay products.

Underclay complex below Cambridge (Pine Creek) marine zone: moderately important potential source of material for structural clay products.

Siltstone and shale sequence overlying Brush Creek marine zone: major source of random fill material; crushed siltstones give good service as low-dust road metal with good compaction characteristics. Persistent horizon throughout Sandy Lick Creek watershed and upper part of Bennett Branch watershed.

Underclay complex below Brush Creek coal: moderately important potential source of material for structural clay products.

Mahoning coal: thin, discontinuous coal seam; no economic importance at present. Associated red underclay a minor potential source of material for structural clay products.

Lower Mahoning Sandstone complex: graywacke sandstone with questionable potential as source of material for molding sand; limited potential for low-grade flagging where plane-bedded; good source for heavy riprap; probably poor source for crushed concrete aggregate due to high clay content.

Upper Freeport coal: moderately important coal seam, but missing over large areas due to pre-Mahoning erosion. Accessory underclay may have refractory properties.

Lower Freeport rider underclay: local minor potential source of material for structural clay products; associated limestone very sporadic.

Lower Freeport coal: thick, but frequently very sporadic, coal seam; great difficulty in predicting lateral quantity and quality; detailed subsurface study necessary for exploitation; absent in places due to pre-Mahoning erosion. Accessory underclay a minor local potential source of material for structural clay products; associated limestone very sporadic.

Upper Kittanning coal: locally important, but sporadic, coal; not extensively mined in this map area, detailed subsurface study necessary for exploitation.

Johnstown Limestone: actually part of Upper Kittanning underclay complex; locally thick (10± ft) deposit of argillaceous limestone with potential as local source of agricultural lime and as water-neutralizing agent in coal mining operations. Associated underclay a potential source of material for structural clay products; some potential for refractory clay.

Middle Kittanning coal: this coal of only moderate importance; sometimes mined as an accessory coal with Lower Kittanning no. 3 in open-pit operations. Accessory underclay a locally important, potential source of material for structural clay products; some additional potential as source of adsorbent/absorbent material.

Lower Kittanning no. 3 coal: principal coal seam in map area; widely mined; reserves include 150 million short tons over 28 inches thick as of 1970; further exploratory drilling recommended in Sabula region. Accessory underclay complex a major source of material for structural clay products; some potential for refractory clay products. Laterally persistent deposit.

Vanport Limestone: thin and very poorly exposed in this map area; no known exploitation at present; possible source of agricultural lime, potential source of water-neutralizing agent in coal mining operations. Drilling necessary to define limits of occurrence.

Clarion coals: thin and sporadic; no economic importance at present. Accessory underclays and clay shales potential sources of material for structural clay products. Accessory siltstones may give moderate service as road metal or random fill.

Homewood Sandstone: considerable potential as source of silica for certain refractory products, usable source for crushed stone; very good properties for dimension stone. Widely exposed from Stony Run at southern border to Laurel Run on eastern border of map area.

Mercer coals: local and very sporadic sources of low-quality, high-ash coal. No economic importance at present. Accessory underclays may serve as minimal sources of material for structural clay products.

Pottsville sandstones (basal conglomeratic units): moderate to considerable potential as source of material for silica brick and crushed aggregate, may serve well as source for furnace bottom sand, ganister mix, and molding sand. Local source of pebbly dimension stone for decorative purposes. Unit exposed at higher elevations over northwestern third of map area, following trend of Boone Mountain.

Burgoon Sandstone: poorly exposed graywacke sandstone with limited potential for molding sand and riprap; poor material for crushed concrete aggregate, serves well as road base material, poor-quality dimension stone. Exposures limited to valleys of Laurel Run and Lick Run in southeastern corner of map area, with small exposure along Stony Run at southern border of area. Unit decreases in thickness to zero in Punxsutawney-Caledonia syncline; unit absent at northern part of map area.

"Patton" red beds: small, local source of red clay shale and claystone with potential for structural clay products, local source of siltstone for road metal and random fill, sparse, thin-bedded sandstones might serve as low-grade flagging. Exposures limited to southeastern part of map area. Serves as stratigraphic marker in subsurface studies.

"Lower complex" of Pocono Formation: local and sporadic occurrences of thin-bedded sandstone with small potential for low-grade flagging, red and green siltstone may serve as local source of low-dust road metal or random fill, minimal potential for clay shale, yielding structural clay products. Exposures mostly in valleys of Rattlesnake Creek, Whetstone Branch, and Wilson Run in northern and northwestern part of map area.

GROUND-WATER CHARACTERISTICS

Seldom used as a source of ground water. Wells yield moderate quantities due to high clay content. Water is generally of poor quality.

Where above local base level, well yields range from less than 1 gpm to 20+ gpm, and water quality is usually good. When the lowest portion of this group lies just below base level, wells which tap that part may have yields as high as 50 gpm, but the water is usually acidic and high in iron due to mining activities.

Wells in this group commonly produce 10 to 25 gpm. Yields up to 100 gpm can be obtained from sandstones which may locally thicken and have a significant lateral extent, and which occur near stream level. The formations within the Allegheny Group are difficult to differentiate based on well yields. Ground water is usually of fair quality except where influenced by mining activities.

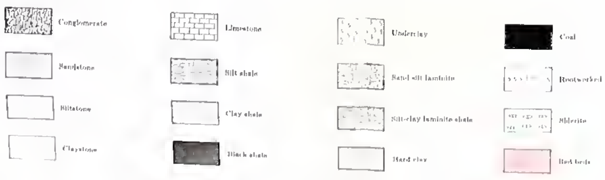
The Elliott Park Formation, when fully saturated, can often supply over 100 gpm to wells. Under artesian conditions,* several hundred gpm can often be obtained. The Curwensville Formation, because of a lesser proportion of sandstone in its thickness, yields significantly less water. In the flat upland areas where the Pottsville occurs, its saturated thickness is small, and only domestic supplies can be obtained. Ground water from this group can be expected to have a high to very high iron content. Hardness may also be high.

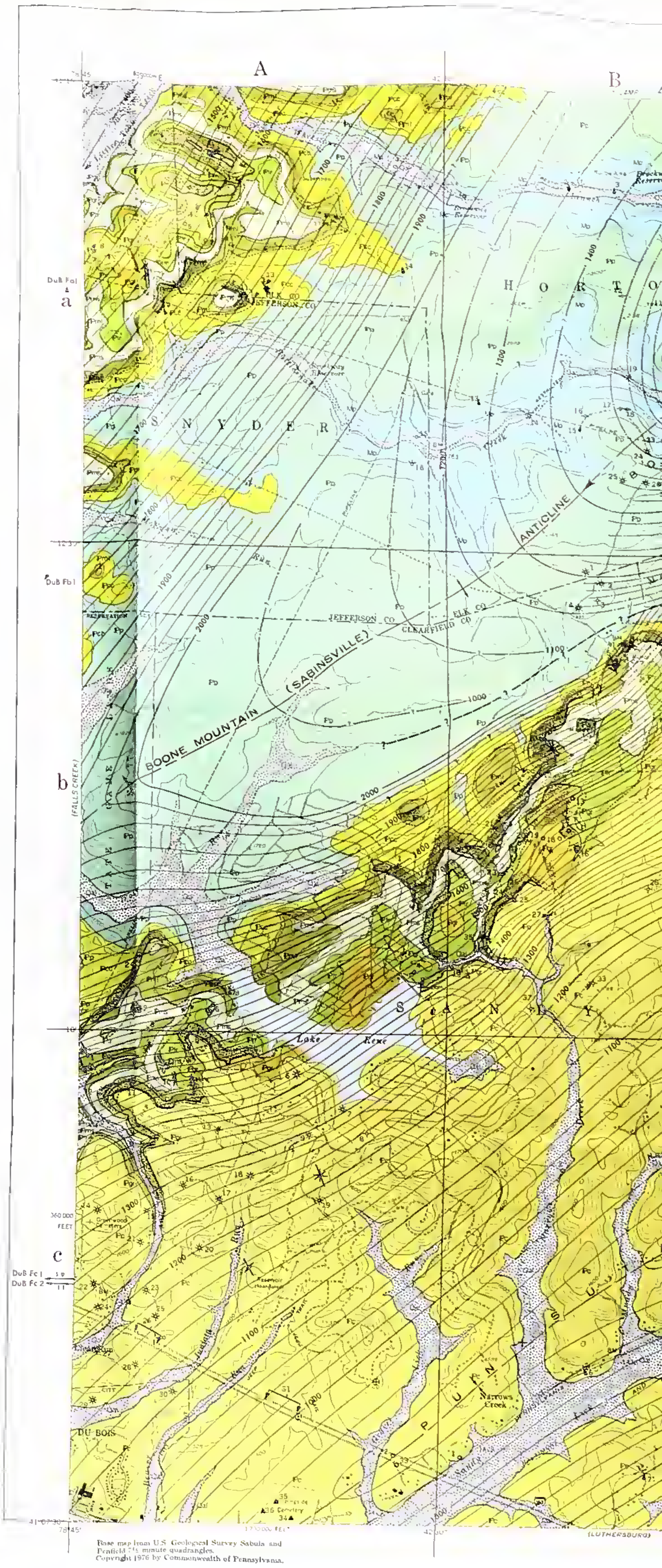
The lower members are unimportant as a source of ground water, yielding only enough for domestic use. Wells in the Burgoon Member, when it is fully saturated, may sometimes yield over 100 gpm. Under artesian conditions,* 400 gpm has been obtained from wells in the Burgoon. Ground water in the Pocono Formation is usually of good quality.

*Artesian conditions occur along the flanks of the major anticlines and along the axis of the syncline. The Burgoon and Elliott Park sandstones along the center of the Punxsutawney-Caledonia syncline are several hundred feet below base level and may contain salt water.

*Due to inferred pre-Pennsylvanian regional upwarping and development of an unconformity, the Pottsville Group lies on successively older Mississippian strata to the north. At the northern edge of this report area, Pottsville conglomerates rest on the lower member of the Pocono Formation. That the loss of Mississippian lithostratigraphic units to the north is due to nondeposition, rather than erosion, is an alternative worthy of consideration.

LITHOLOGIC SYMBOLS USED IN COLUMNAR SECTION





Base map from U.S. Geological Survey Sabula and Penfield 7½ minute quadrangles.
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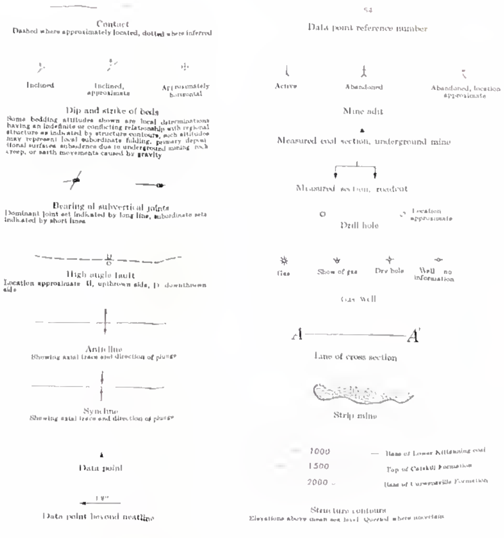
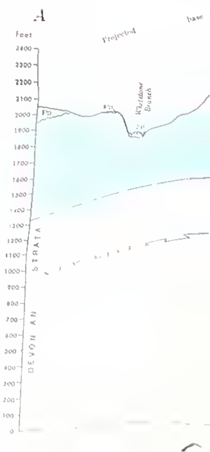
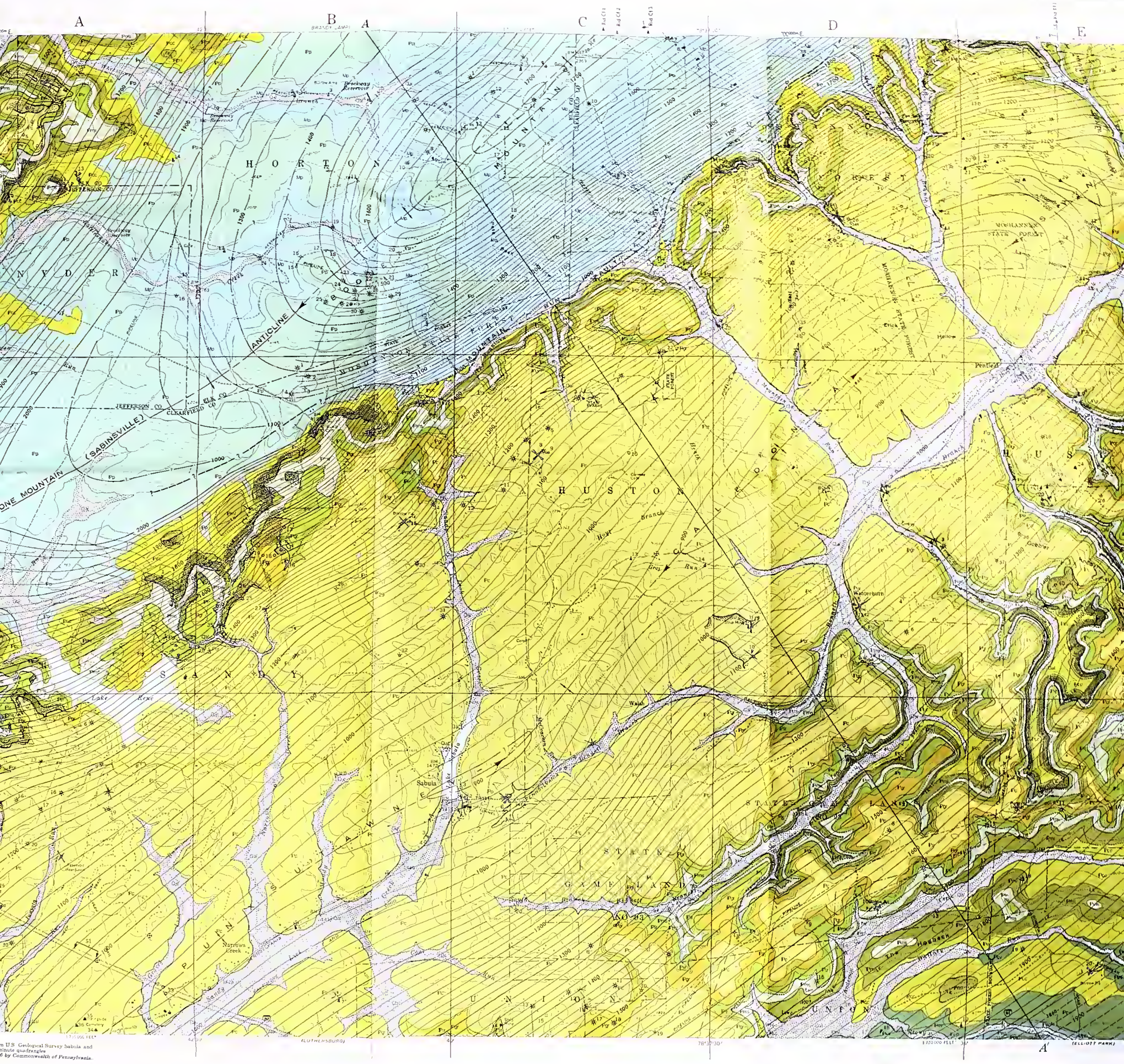
SYMBOLS


Contact
Dashed where approximately located, dotted where inferred
Inclined
Inclined, approximate
Approximately horizontal
Dip and strike of beds
Some bedding attitudes shown are local determinations having an indefinite or conflicting relationship with regional structure as indicated by structure contours; such attitudes may represent local subordinate folding, primary depositional surfaces, subsidence due to underground mining, rock creep, or earth movements caused by gravity
Bearing of subvertical joints
Dominant joint set indicated by long line, subordinate sets indicated by short lines
U
D
High angle fault
Location approximate. U, upthrown side, D, downthrown side
Anticline
Showing axial trace and direction of plunge
Syncline
Showing axial trace and direction of plunge
Data point
19°
Data point beyond neatline
54
Data point reference number
Active
Abandoned
Abandoned, location approximate
Mine adit
Measured coal section, underground mine
Measured section, roadcut
Location approximate
Drill hole
Gas
Show of gas
Dry hole
Well no information
Gas Well
A
A'
Line of cross section
Strip mine
1000
1500
2000
Base of Lower Kittanning coal
Top of Catskill Formation
Base of Curwensville Formation
Structure contours
Elevations above mean sea level. Queried where uncertain

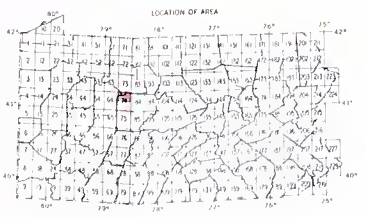


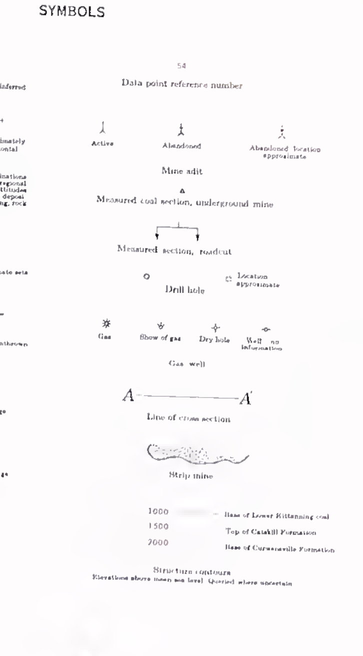


m U.S. Geological Survey Sabula and
inute quadrangles
6 by Commonwealth of Pennsylvania.

GEOLOGIC MAP OF THE SABULA AND PENFIELD QUADRANGLE
CLEARFIELD, ELK, AND JEFFERSON COUNTIES, PENNSYLVANIA

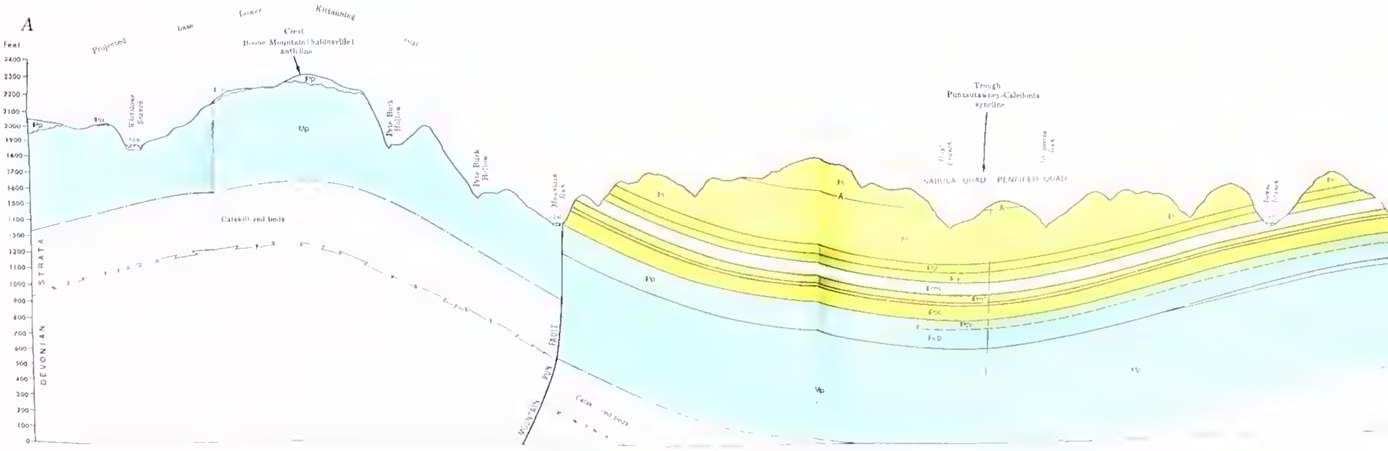
BY
THOMAS M. BERG AND ALBERT D. GLOVER
1976

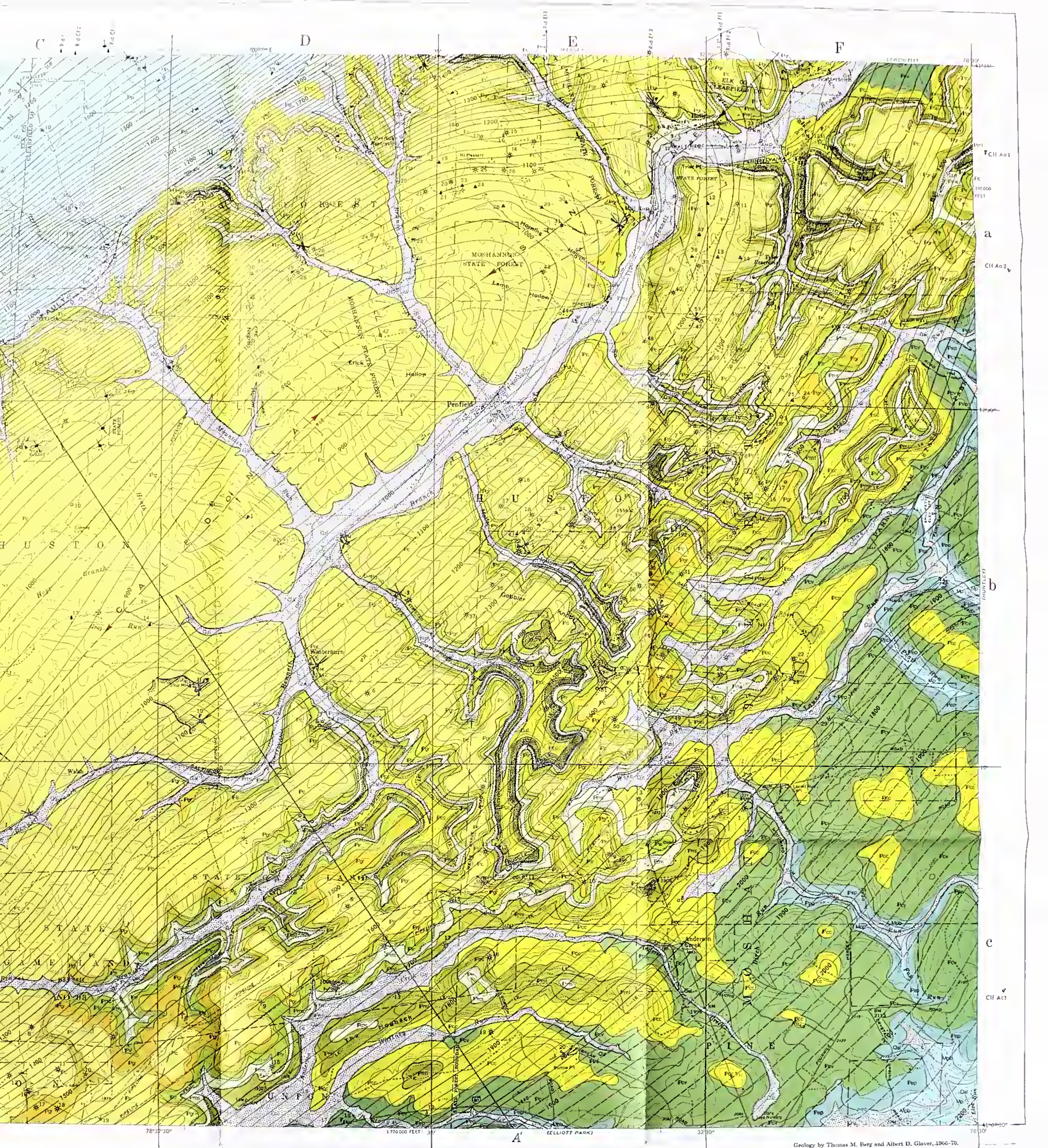



SYMBOLS
54
Data point reference number
Active
Abandoned
Abandoned location approximate
Mine adit
Measured coal section, underground mine
Measured section, roadcut
Drill hole
Location approximate
Gas
Show of gas
Dry hole
Well no information
Gas well
A
A'
Line of cross section
Strip mine
1000
1500
2000
Base of Lower Kittanning coal
Top of Catskill Formation
Base of Curwensville Formation
Structure contours
Elevations above mean sea level. Queried where uncertain

CROSS SECTION

(Horizontal scale same as map scale, vertical exaggeration X5)





Geology by Thomas M. Berg and Albert D. Glover, 1966-70.
John G. Kuchinski, Virginia M. Milewski, and
Albert E. VanOlden, Cartographers.

GEOLOGIC MAP OF THE SABULA AND PENFIELD QUADRANGLES, CLEARFIELD, ELK, AND JEFFERSON COUNTIES, PENNSYLVANIA

BY

THOMAS M. BERG AND ALBERT D. GLOVER

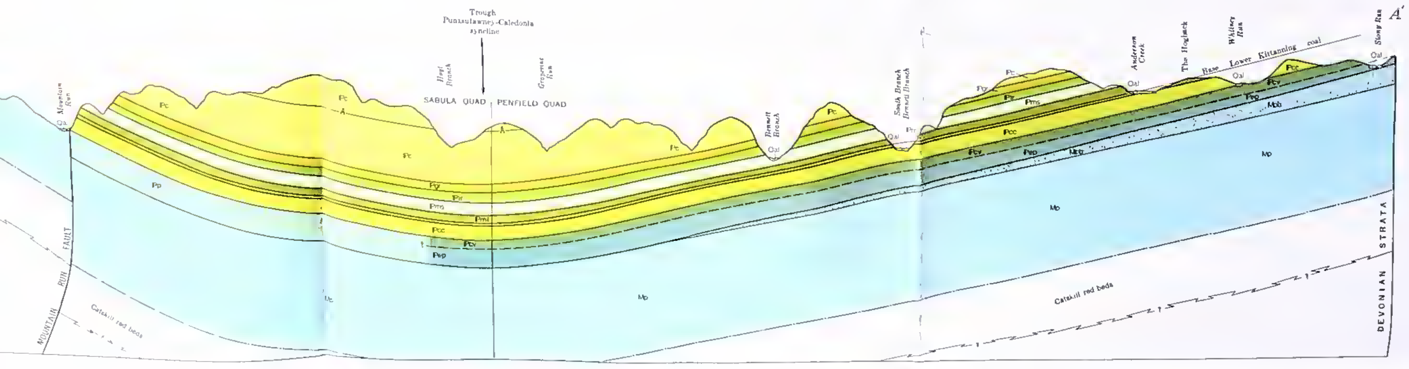
1976

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

CROSS SECTION

(Horizontal scale same as map scale; vertical exaggeration X5)



COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

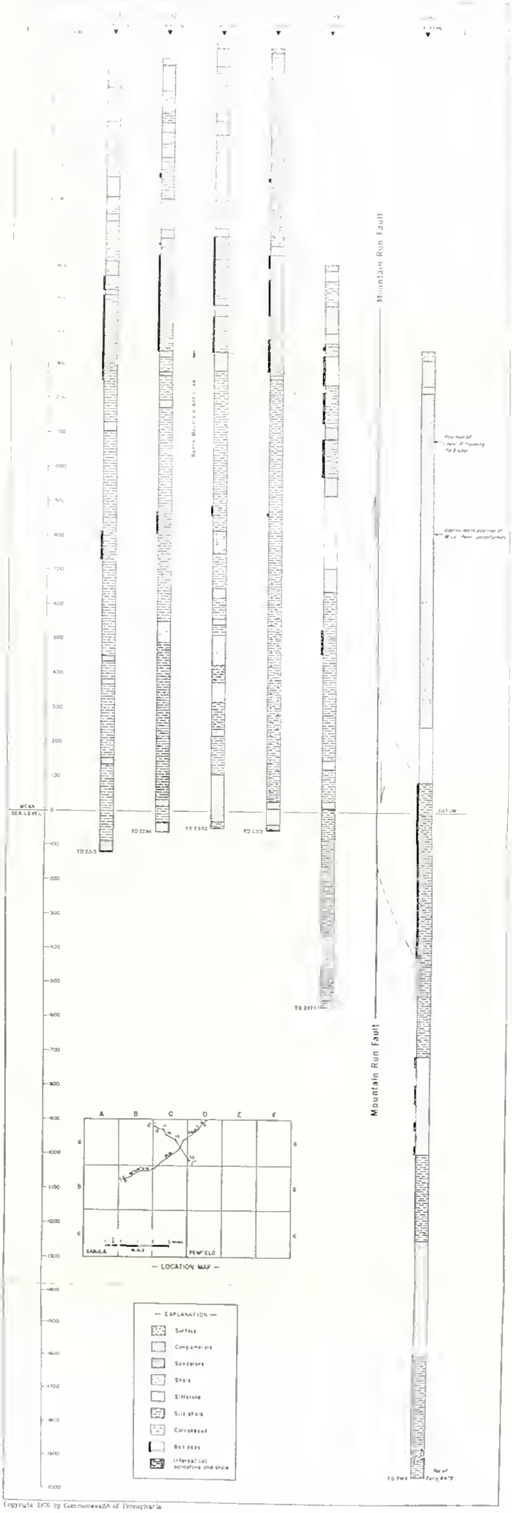


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PLATE 2. SECTIONS FROM GAS WELL RECORDS SHOWING UPPER DEVONIAN, MISSISSIPPIAN, AND PENNSYLVANIAN STRATA ACROSS THE MOUNTAIN RUN FAULT AND BOONE MOUNTAIN ANTICLINE (Diagrammatic sections of drillers' logs are shown as interpreted by the authors)

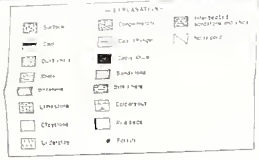
TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow State Geologist

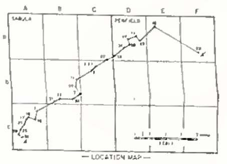
COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES

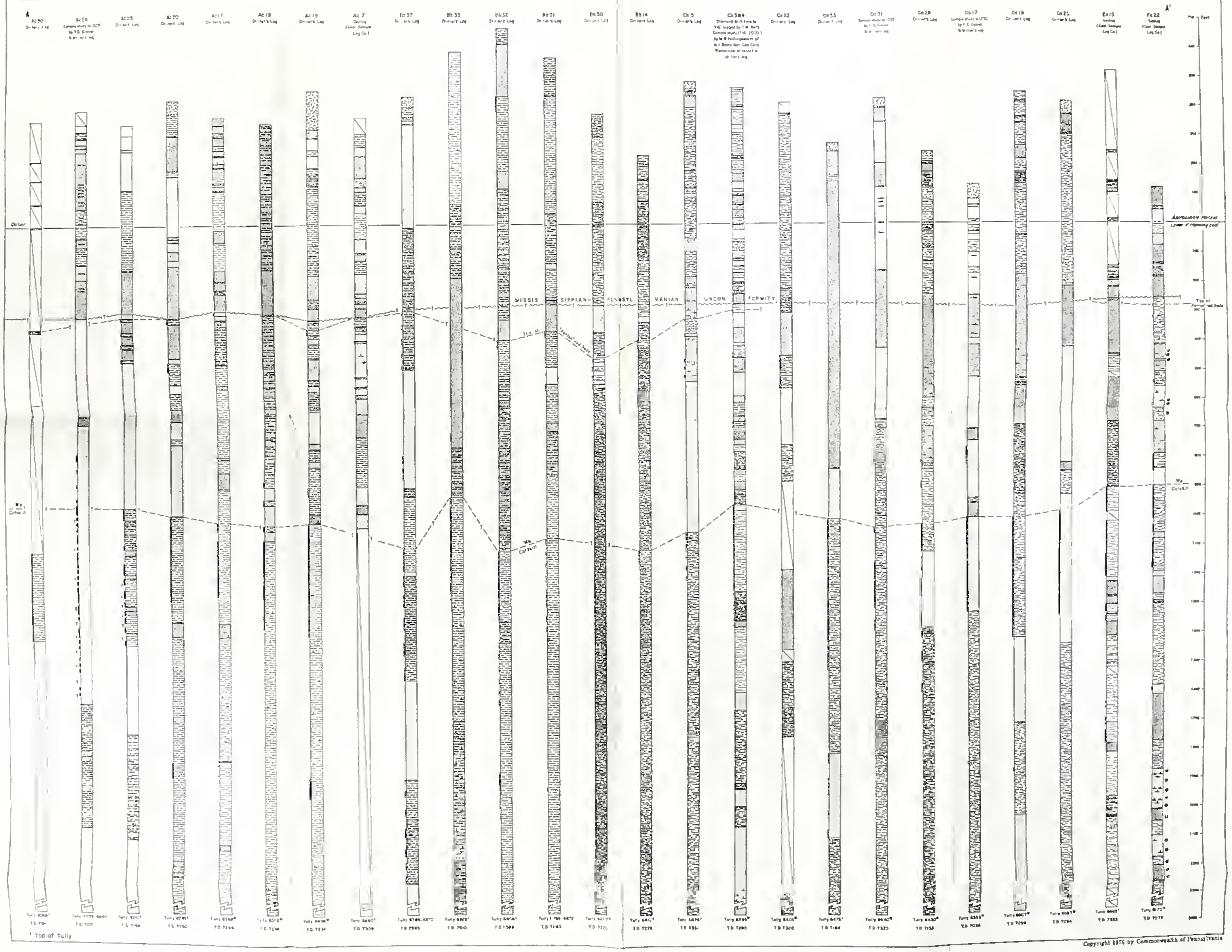
Atlas 74ab, Plate 3
(Plate 7 on reverse side)

PLATE 3. SECTIONS FROM GAS WELL RECORDS SHOWING UPPER DEVONIAN, PENNSYLVANIAN, AND MISSISSIPPIAN STRATA

(Diagrammatic sections of drillers' logs are shown as interpreted by the authors)







* Top of Tully

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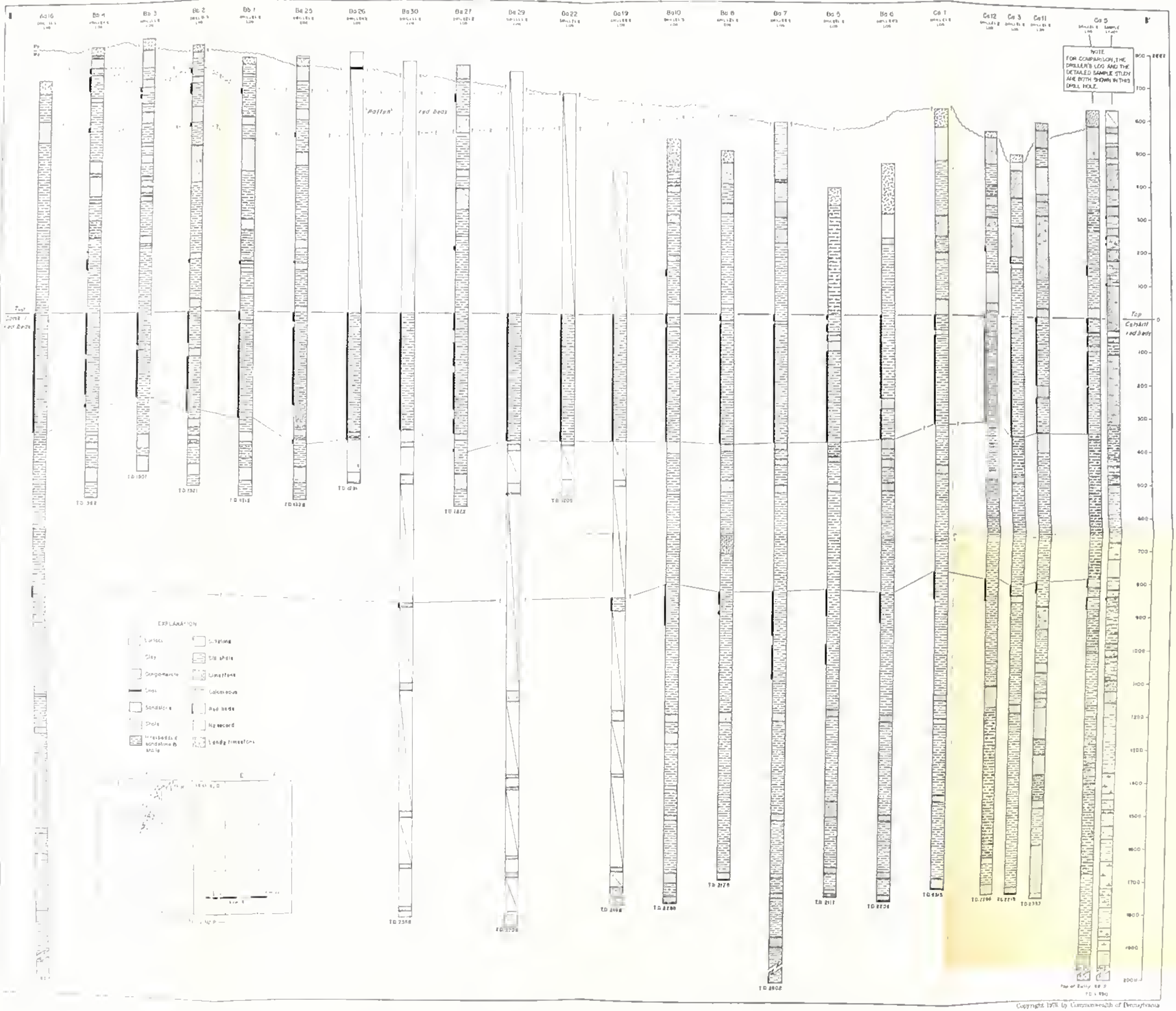

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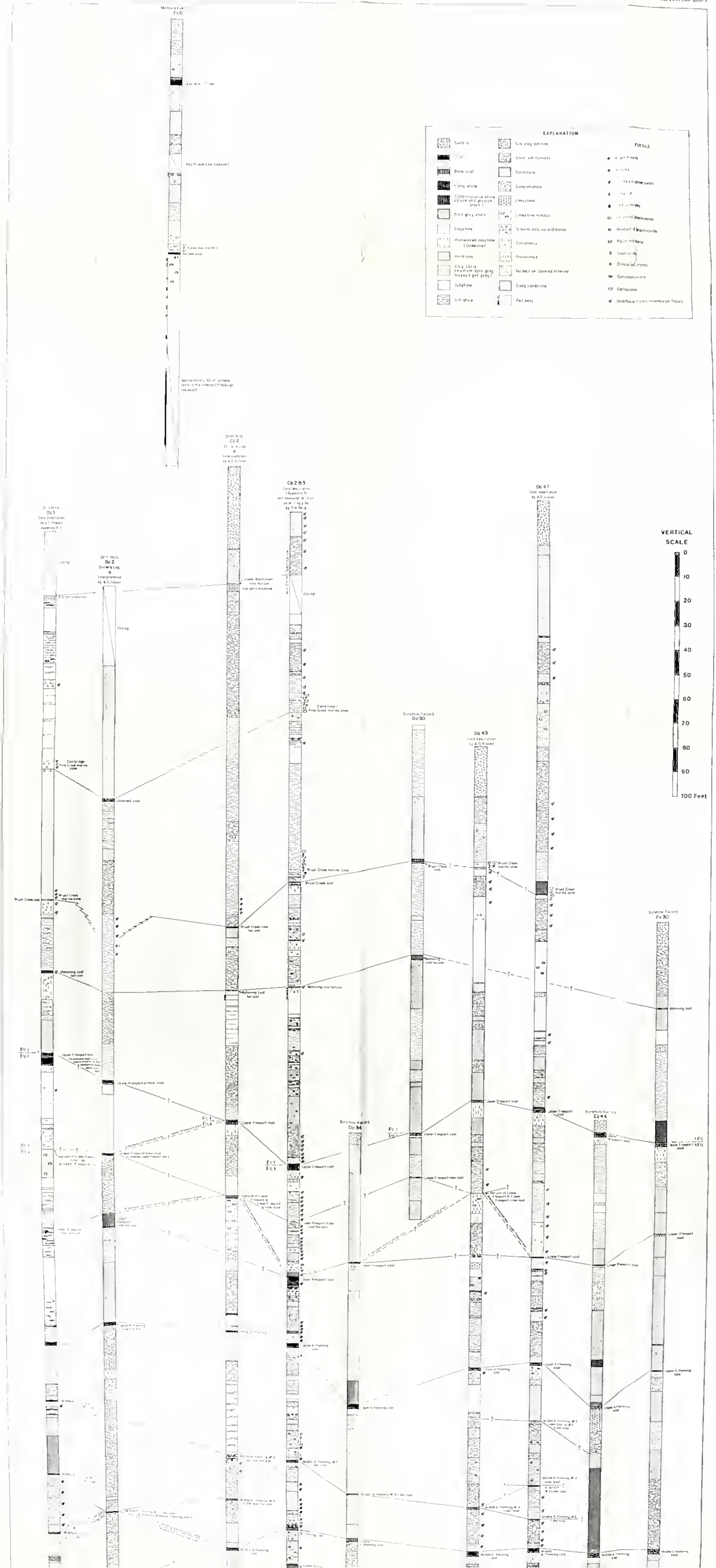
PLATE 4. SECTIONS FROM GAS WELL RECORDS SHOWING UPPER DEVONIAN, MISSISSIPPIAN, AND BASAL PENNSYLVANIAN STRATA

(Diagrammatic sections of drillers' logs are shown as interpreted by the authors)

TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES

Atlas 74ab, Plate 5
(Plate 8 on reverse side)



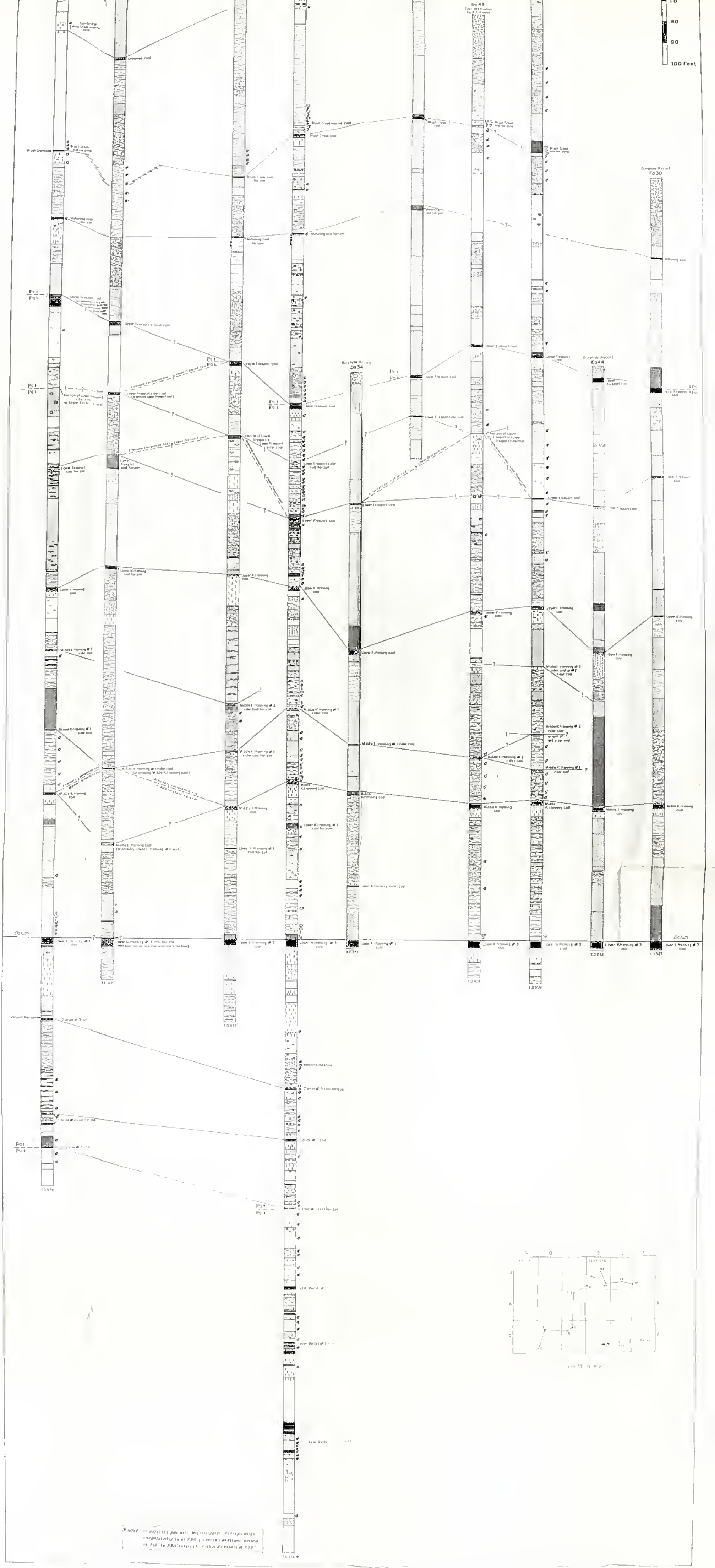


PLATE 5. LONG DRILL HOLES AND MEASURED SECTIONS SHOWING PENNSYLVANIAN STRATA

TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES

Atlas 74ab, Plate 6
(Plate 10 on reverse side)

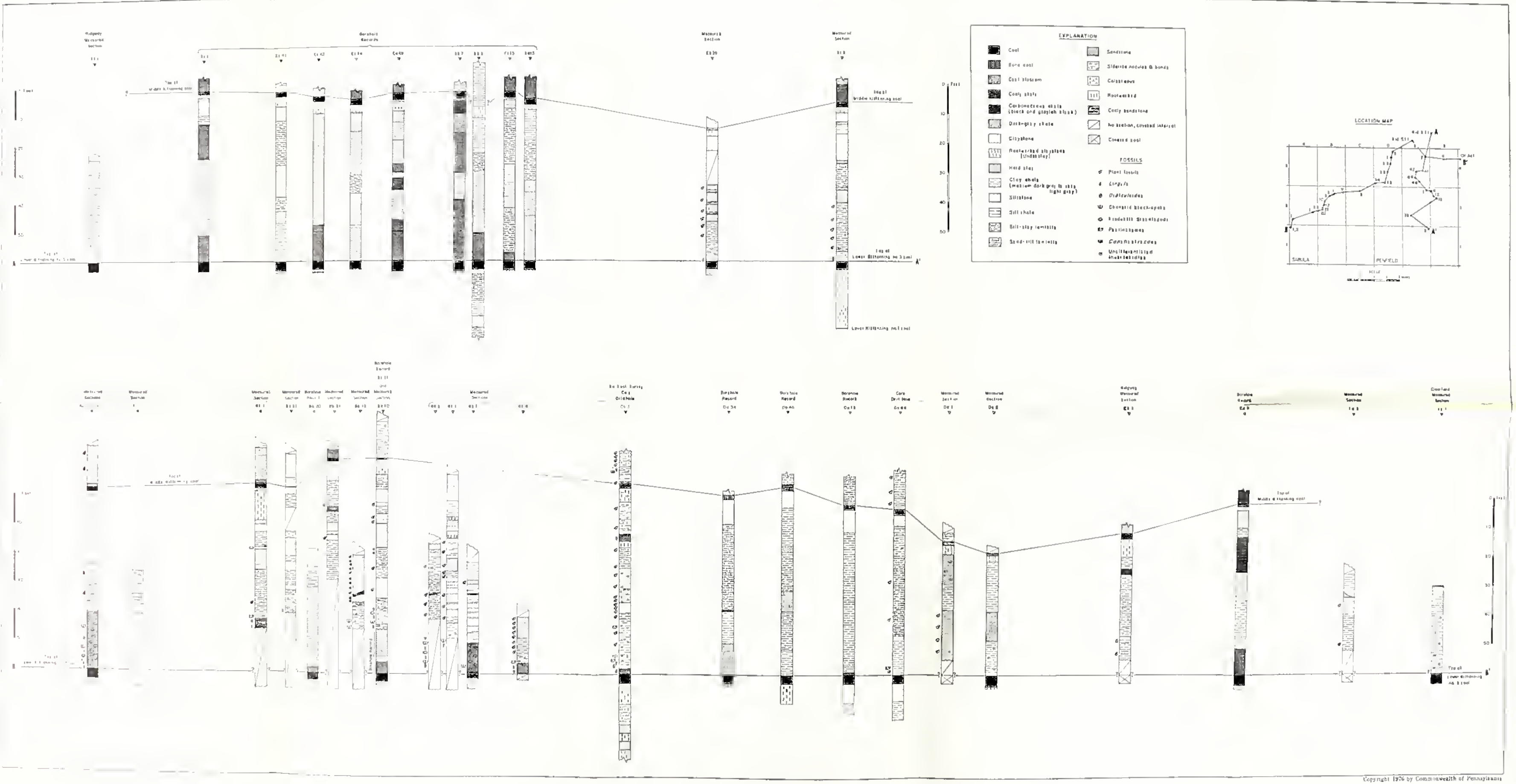


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PLATE 6. MILLSTONE RUN FORMATION STRATIGRAPHIC SECTIONS

[illegible] SURVEY

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES

Atlas 74ab, Plate 7
(Plate 8 on reverse side)

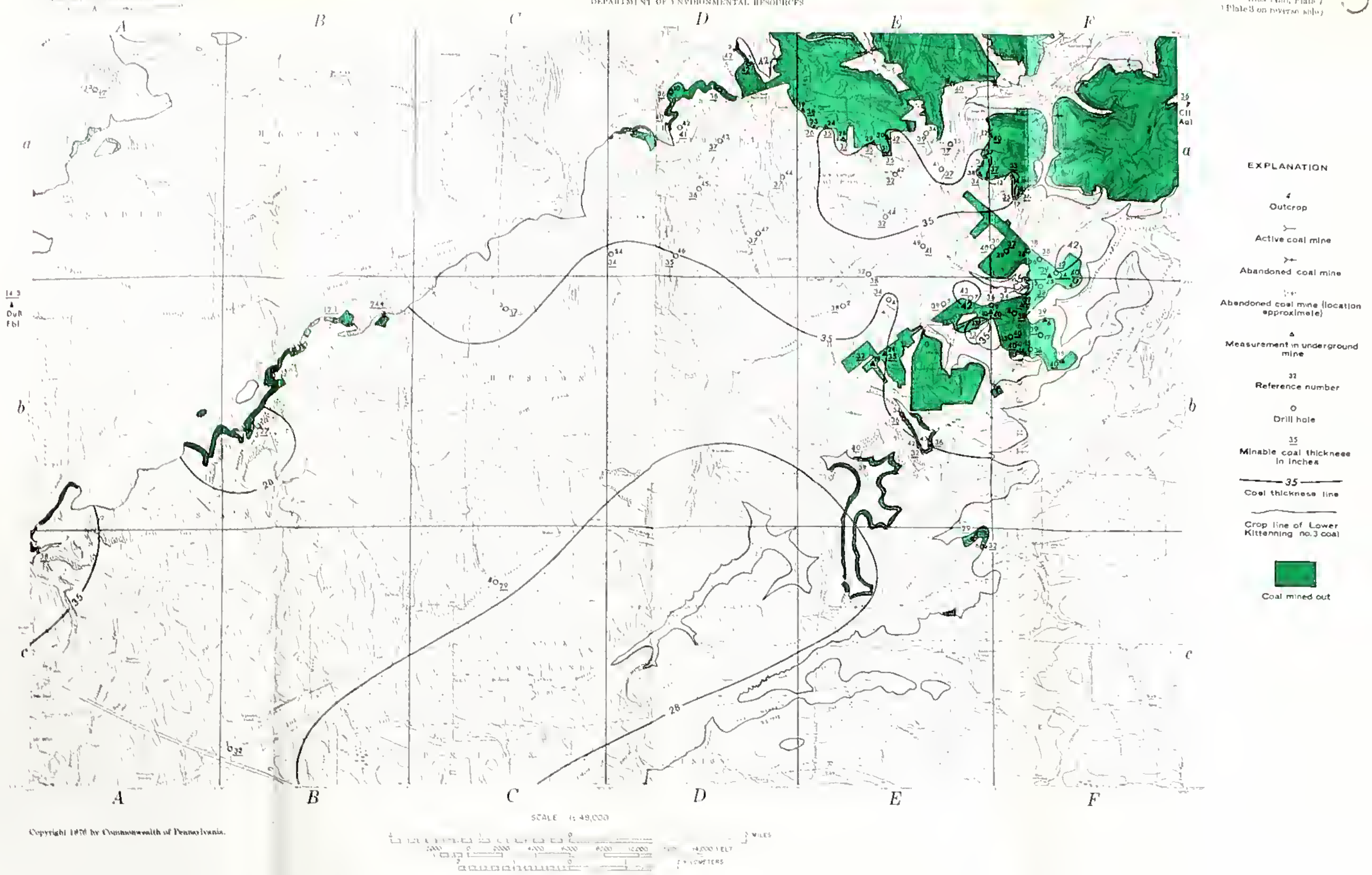

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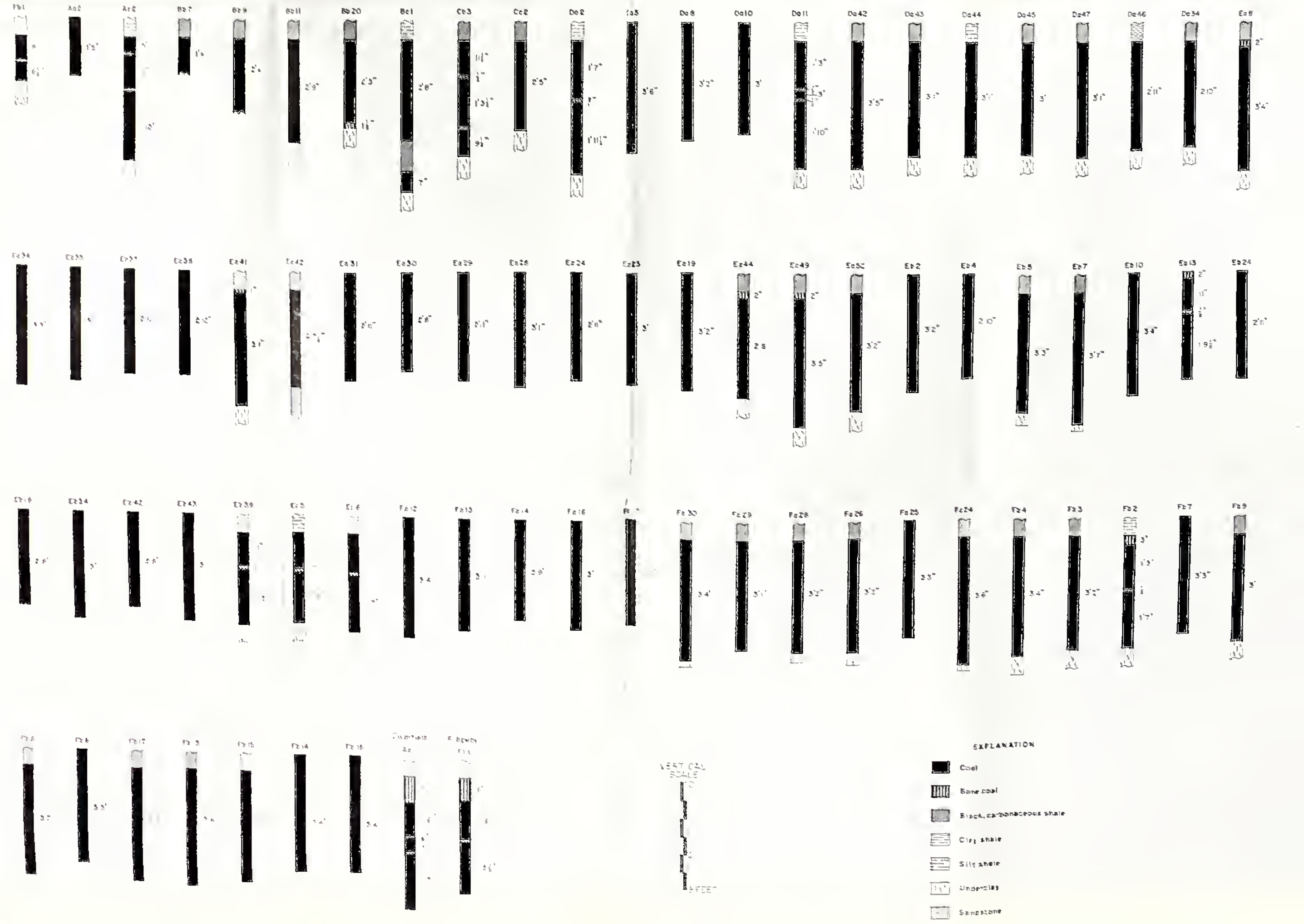
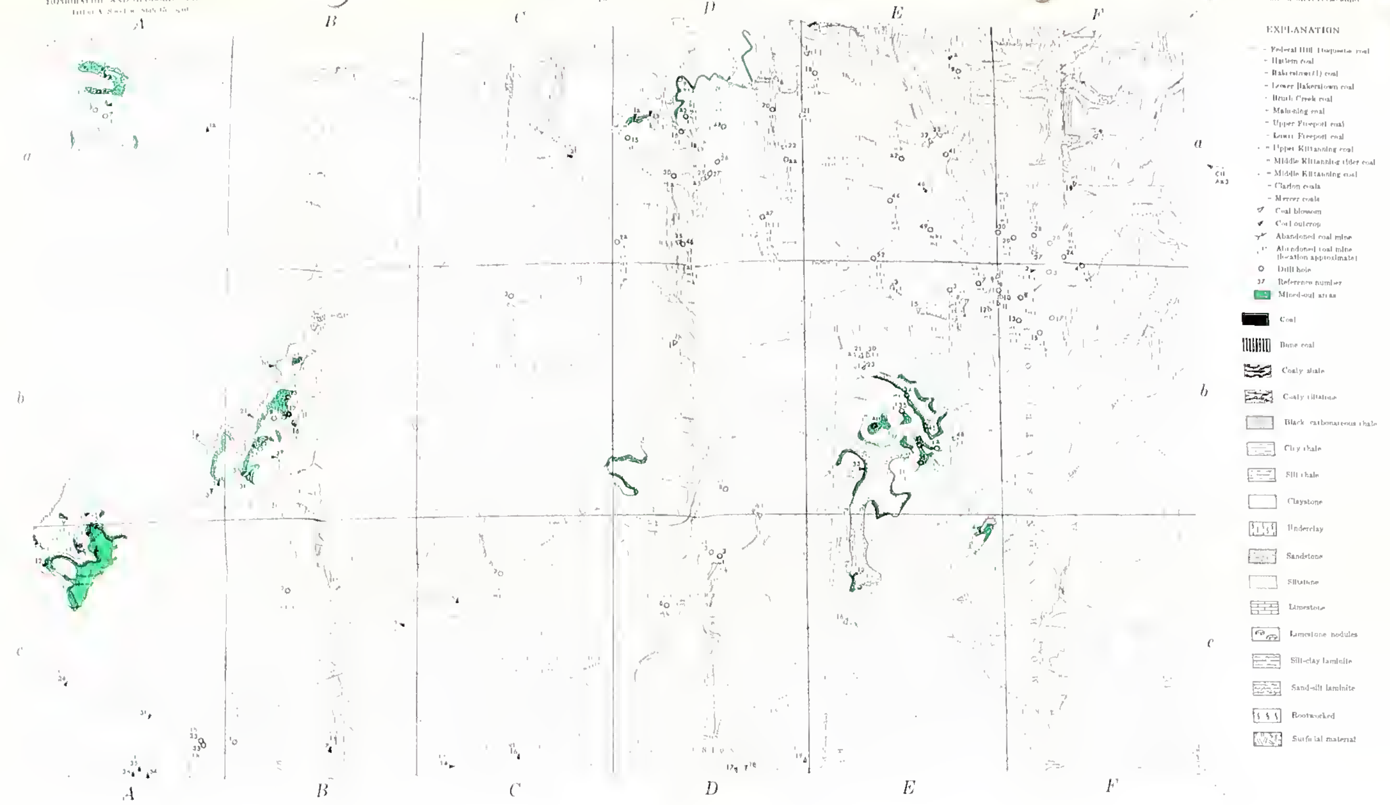
PLATE 7. LOWER KITTANNING NO. 3 COAL RESERVES AND MEASURED SECTIONS



TOPOGRAPHIC AND GEOLOGIC SURVEY
[illegible]

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES



EXPLANATION

- Federal Hill (Duquesne) coal
- Harlem coal
- Bakerstown(?) coal
- Lower Bakerstown coal
- Brush Creek coal
- Mahoning coal
- Upper Freeport coal
- Lower Freeport coal
- Upper Kittanning coal
- Middle Kittanning rider coal
- Middle Kittanning coal
- Clarion coals
- Mercer coals
- Coal blossom
- Coal outcrop
- Abandoned coal mine
- Abandoned coal mine (location approximate)
- Drill hole
- Reference number
- 🟩 Mined-out areas
- Coal
- Bone coal
- Coaly shale
- Coaly siltstone
- Black carbonaceous shale
- Clay shale
- Silt shale
- Claystone
- Underclay
- Sandstone
- Siltstone
- Limestone
- Limestone nodules
- Silt-clay laminite
- Sand-silt laminite
- Rootworked
- Surficial material

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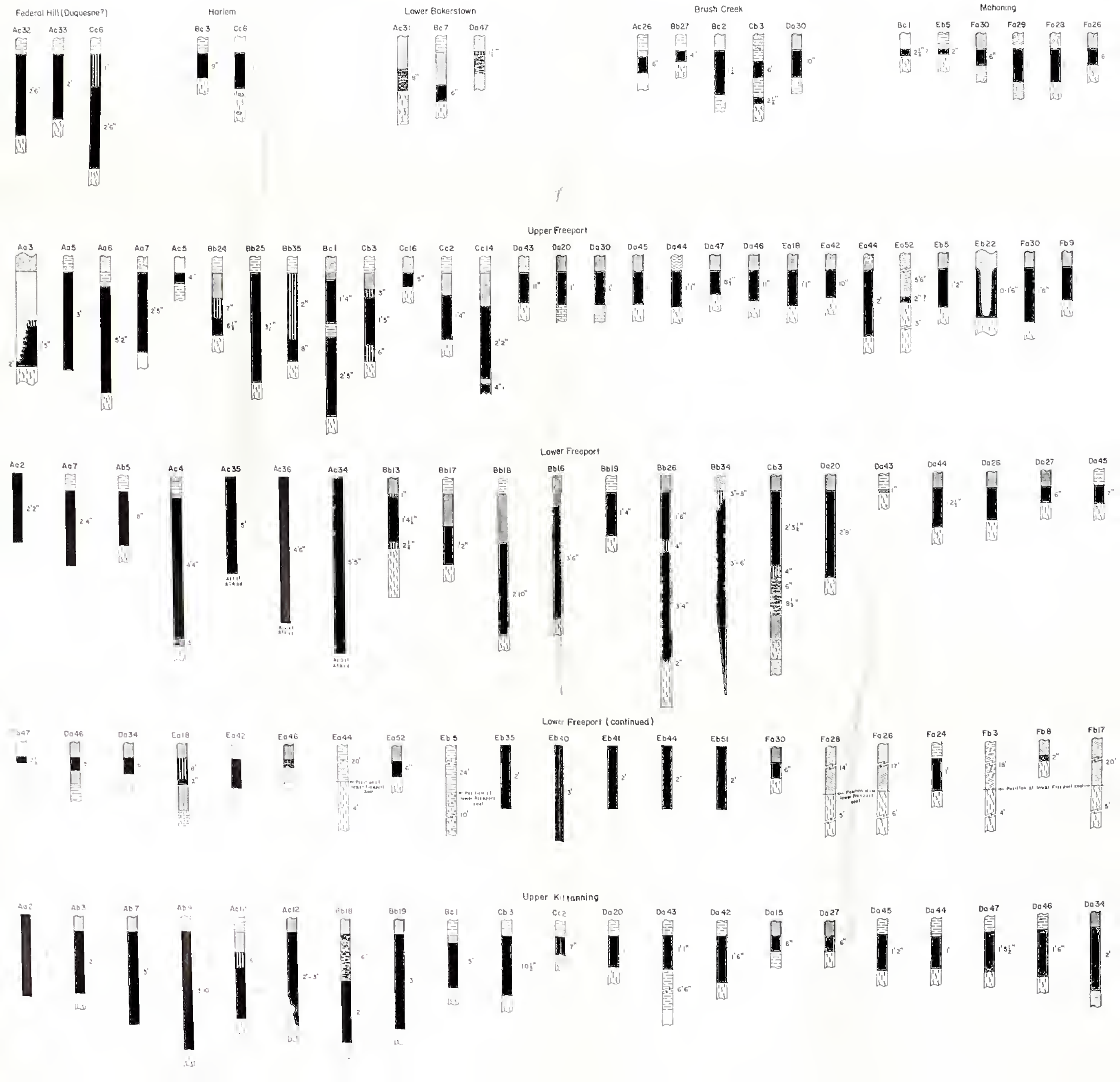
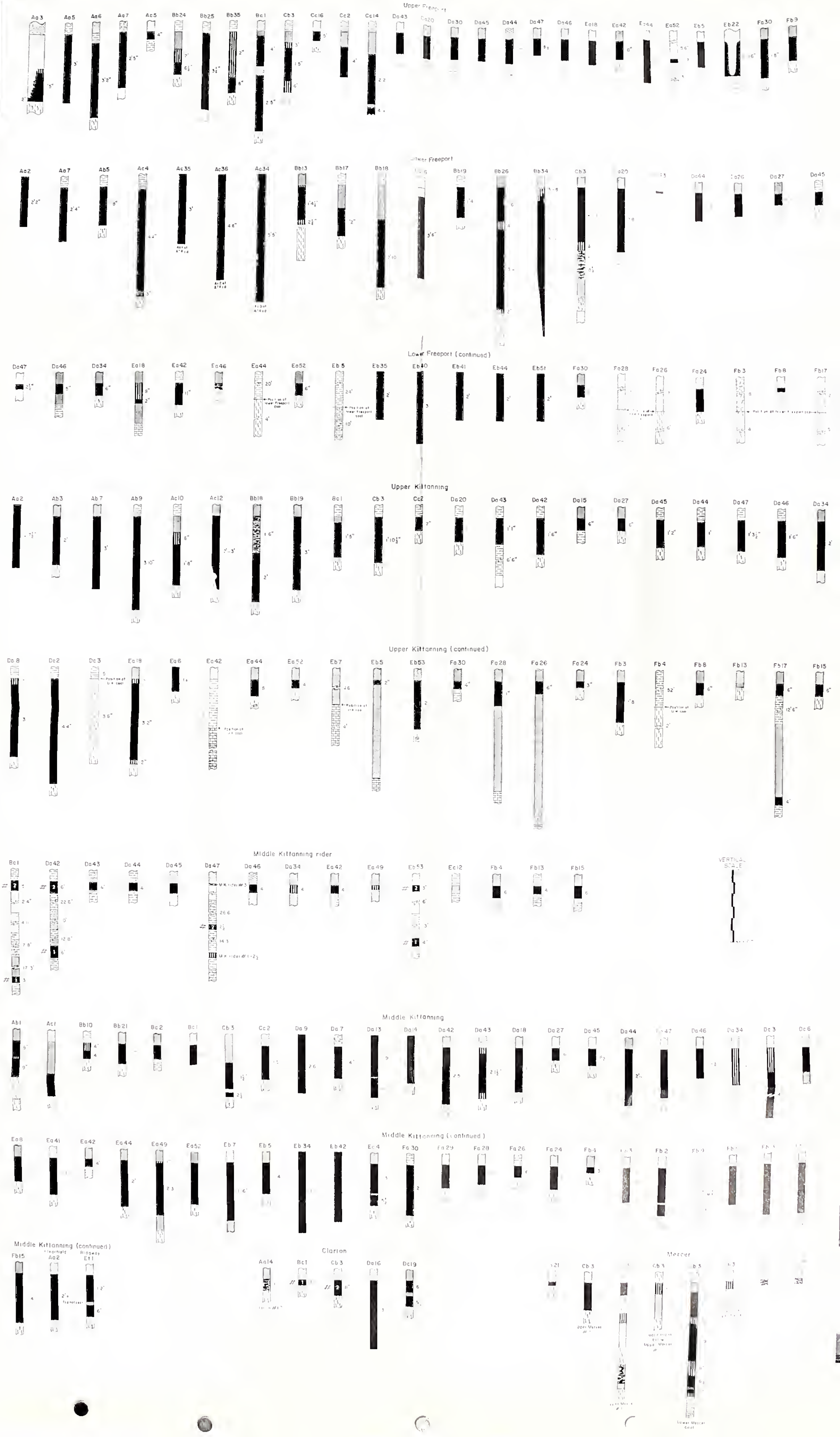
PLATE 8. ADDITIONAL COALS AND MINED-OUT AREAS

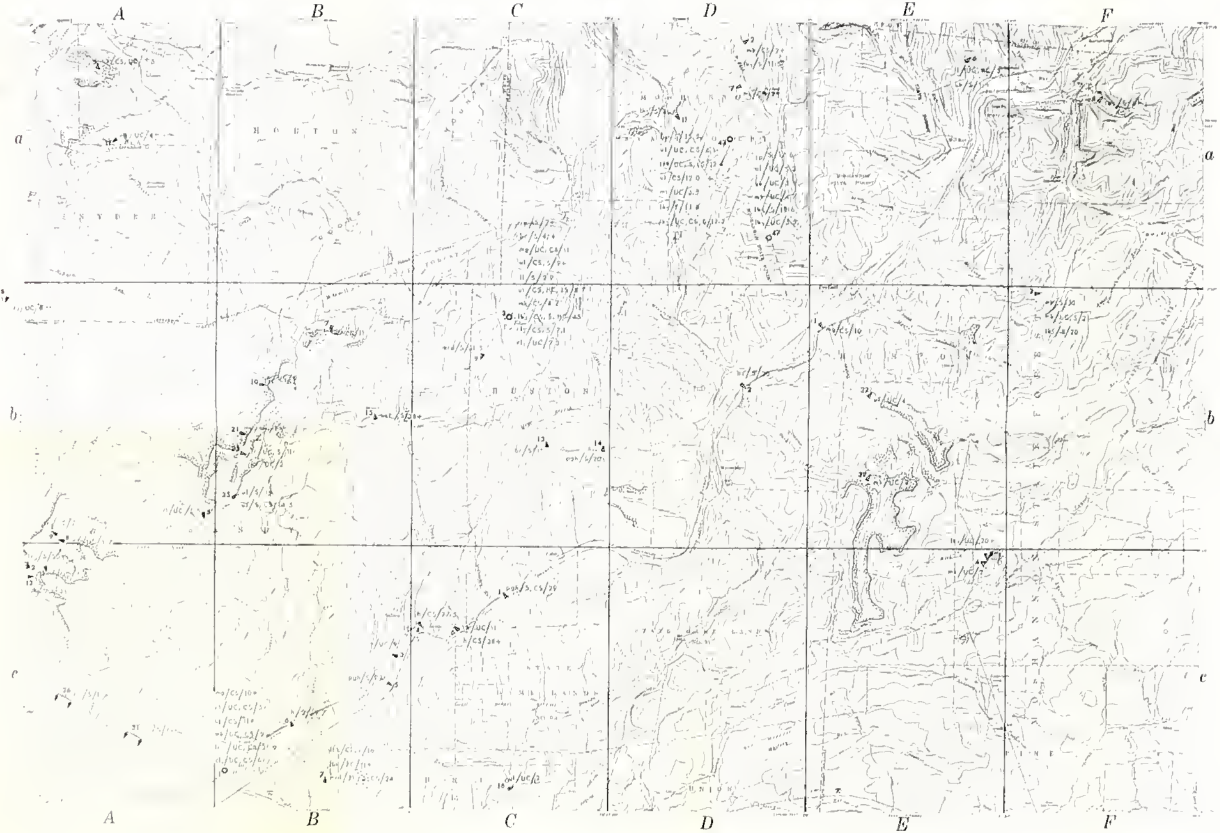



Upper Freeport
Aa3
Aa5
Aa6
Aa7
Ac5
Bb24
Bb25
Bb35
Bc1
Cb3
Cc16
Cc2
Cc14
Da43
Da20
Da30
Da45
Da44
Da47
Da46
Ea18
Ea42
Ea44
Ea52
Eb5
Eb22
Fa30
Fb9
Lower Freeport
Aa2
Aa7
Ab5
Ac4
Ac35
Ac36
Ac34
Bb13
Bb17
Bb18
Bb19
Bb26
Bb34
Cb3
Da14
Da26
Da27
Da45
Lower Freeport (continued)
Da47
Da46
Da34
Ea18
Ea42
Ea46
Ea44
Ea52
Eb5
Eb35
Eb40
Eb41
Eb44
Eb51
Fa30
Fa28
Fa26
Fa24
Fb3
Fb8
Fb17
Position of lower Freeport coal
Upper Kittanning
Aa2
Ab3
Ab7
Ab9
Ac10
Ac12
Bb18
Bb19
Bc1
Cb3
Cc2
Da20
Da43
Da42
Da15
Da27
Da45
Da44
Da47
Da46
Da34
Upper Kittanning (continued)
Db8
Dc2
Dc3
Ea19
Ea6
Ea42
Ea44
Ea52
Eb7
Eb5
Eb53
Fa30
Fa28
Fa26
Fa24
Fb3
Fb4
Fb8
Fb13
Fb17
Fb15
Position of U.K. coal
Middle Kittanning rider
Bc1
Da42
Da43
Da44
Da45
Da47
Da46
Da34
Ea42
Ea49
Eb53
Ec12
Fb4
Fb13
Fb15
VERTICAL SCALE
Middle Kittanning
Ab1
Ac1
Bb10
Bb21
Bc2
Bc1
Cb3
Cc2
Da9
Da7
Da13
Da14
Da42
Da43
Da18
Da27
Da45
Da44
Da47
Da46
Da34
Dc3
Dc6
Middle Kittanning (continued)
Ea8
Ea41
Ea42
Ea44
Ea49
Ea52
Eb7
Eb5
Eb34
Eb42
Ec4
Fa30
Fa29
Fa28
Fa26
Fa24
Fb4
Fb3
Fb2
Middle Kittanning (continued)
Fb15
Clearfield Aa2
Ridgway Et1
Clarion
Aa14
Bc1
Cb3
Da16
Dc19
Mercer
Cb3
Upper Mercer
Lower Mercer coal

TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, State Geologist

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES

Atlas 74ab, Plate 9
(Plate 4 on reverse side)



EXPLANATION

Identification of Stratigraphic Horizon

bt — Barton
fh — Federal Hill-Duquesne
h — Harlem
pgh — Pittsburgh (red beds)
lbk — Lower Bakerstown
mey — Meyersdale (red beds)
cb — Cambridge (Pine Creek)
b — Brush Creek
mg — Mahoning
uf — Upper Freeport
lf — Lower Freeport
uk — Upper Kittanning
mk — Middle Kittanning
lk_3 — Lower Kittanning no. 3
cl_2 — Clarion no. 2
cl_1 — Clarion no. 1

Symbols

◂ Outcrop location
○ Drill hole
7 Reference number
Thickness in feet

Lithologies

uc — Underclay
cs — Claystone
pc — Plastic clay
hc — Hard clay
s — Shale
ls — Limestone

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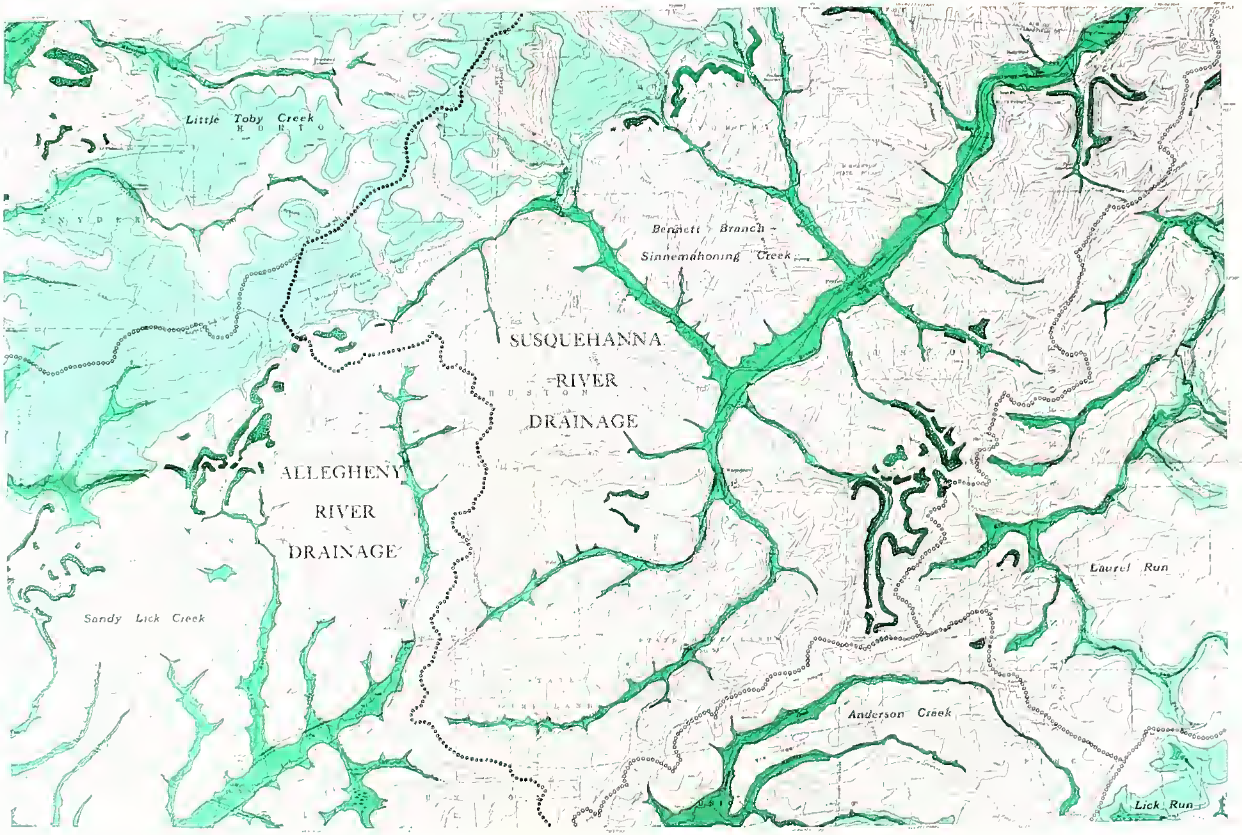
SCALE 1: 48,000
2 MILES
2000 0 2000 4000 6000 8000 10,000 12,000 14,000 FEET
2 KILOMETERS

PLATE 9. LOCATION OF MEASURED CLAY AND CLAY SHALE SECTIONS

TOPOGRAPHIC AND GEOLOGIC SURVEY
Arthur A. Socolow, *State Geologist*

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF ENVIRONMENTAL RESOURCES

Atlas 74ab, Plate 10
(Plate 6 on reverse side)



SCALE 1:48,000

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EXPLANATION

🟩

Excellent foundations, difficult excavation.

Predominantly sandstone; conglomerate in lower part of Pp.
Ppo (includes Pp where undivided),
Mpo (locally in other units). *

Fractures common; usually open and vertical. Makes substantial well-drained foundations. Forms stable cuts except for some surface sloughing along outcrop. Excavation requires extensive blasting and heavy power tools.

☐

Weak to moderately durable foundations. Easy to moderately difficult excavation.

Coal-bearing and heterogeneous sedimentary rocks: interbedded shale, siltstone, thin-bedded sandstone, coal, and underclay. Rare thin limestone. Some local thicker bedded sandstones to 25 feet thick.
Pc, Pgy, Pr, Pms, Pml, Pcc, Pcv *

Non-coal-bearing rocks: interbedded sandstone, siltstone, silt shale and clay shale with sporadic red and green shales. In central and southern portion of area, includes interbedded red, green, and gray shales and siltstones.
Mp *

Fractures common; usually open and vertical, more widely spaced in sandstones and closer spaced in finer grained rocks and coal. Usually provides good foundations and stable cuts except for underclays and red and green shales (Mp) which tend to deform and slump under load when wet. Bedrock should be excavated to competent material. Local thick-bedded sandstone forms stable cuts and excellent foundations. Hardness variable, but often difficult to excavate, requiring drilling and blasting. Good drainage except for relatively impermeable underclays, clay shales, and red and green shales (Mp).

🟩

Poor foundations, easily excavated

Unconsolidated floodplain alluvium composed of clay, silt, sand, pebbles, and cobbles, with lenses of organic material.
Qa *

Forms unstable cuts. Provides poor foundations because of irregular distribution of materials and unconsolidated nature. Subject to flooding. Easily excavated with light power equipment.

🟩

Works of man.

Composed of disaggregated and uncompacted rock material. Includes mine spoils and earthen dams.

Unstable foundation material. Easily excavated. Excellent drainage.

* *Letter symbols refer to geologic units on Plate 1*

PLATE 10. FOUNDATION AND EXCAVATION CONDITIONS AND MAJOR WATERSHEDS